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WATER SURVEY SERIES NO. 14

CHEMICAL AND BIOLOGICAL SURVEY OF THE WATER OF ILLINOIS

REPORT FOR YEAR ENDING DECEMBER 31, 1916

EDWARD BARTOW

DIRECTOR

PUBLISHED BY THE UNIVERSITY OP ILLINOIS
URBANA

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[1]From September. [2]To July. [3]From February. [4]From July. [5]Special summer assistants. [6]From May.

LETTER OF TRANSMITTAL

State of Illinois
Department of Registration and Education
State Water Survey Division

Urbana, Illinois, November 12, 1917.

Edmund J. James, Ph.D., LL.D.,
President, University of Illinois.

Sir: Edward Bartow, Director, is serving as Major in the Sanitary Corps in the American army in France. In his absence I herewith submit a report of the work of the State Water Survey, for the year ending December 31, 1916, and request that it be printed as a bulletin of the University of Illinois, State Water Survey Series No. 14.

The report contains an account of the work done by the State Water Survey in accordance with the laws creating the State Water Survey and imposing upon it new and additional duties (Laws of Illinois, 40th General Assembly, 1897, 12; 47th General Assembly, 1911, 43. (Bull. State Water Survey Series **9**, 7-8).

Summaries of the chemical, biological, and engineering work are given, together with more complete reports on certain special investigations conducted during the year.

Thanks are due the regular staff and graduate students for the interest they have shown in the work. Credit has been given in appropriate places in the bulletin. Thanks are due W. F. Monfort who edited articles for the bulletin.

Bespectfully submitted,
G. C. HABERMEYER, *Acting Chief.*

CHEMICAL AND BIOLOGICAL SURVEY OF THE WATERS OF ILLINOIS

REPORT FOR THE YEAR ENDING DECEMBER 31, 1916

EDWARD BARTOW
Director

GENERAL REPORT

ADMINISTRATION

By authority of the 40th General Assembly of Illinois[1] the Board of Trustees of the University of Illinois in 1897 created the Illinois State Water Survey and made it a division of the Department of Chemistry. The work was extended by the 47th General Assembly in 1911.[2] The State Water Survey is empowered to visit municipal water supplies, to inspect watersheds, to make such field studies and to collect such samples as are necessary, to analyze and test the samples, and to make any investigations to the end that a pure and adequate public water supply for domestic and manufacturing purposes may be maintained in each municipality. Sanitary water analyses are made free of charge when samples are collected according to the directions of the Survey.

During 1916 the laboratory and field work of the State Water Survey was continued along the lines inaugurated late in 1911 and described in Bulletins 9-13. The scope of the work was somewhat extended because the 49th General Assembly increased the appropriation from $21,500 per annum to $23,500 per annum, and made special appropriation of $5,000 to establish a sewage experiment station. The Trustees of the University of Illinois continued the allotment of $7,500 per annum for the educational and scientific work carried on by the Survey and by the Sanitary Division of the Department of Chemistry.

The staff has been considerably changed during the year. Mr. Paul Hansen, engineer for the Survey since 1911, resigned to become

[1]Laws of the State of Illinois 40th General Assembly, 1897, 12.
[2]Laws of the State of Illinois 47th General Assembly, 1911, 43.

Chief Sanitary Engineer for the Illinois State Board of Health. In September, Mr. George Conrad Habermeyer, B.S., University of Illinois, 1903, was appointed acting engineer. Dr. Harry Peach Corson, chemist and bacteriologist, resigned to accept a position with the United States Public Health Service and Mr. Wilfred Francis Langelier, chemist and bacteriologist, resigned to become assistant professor of sanitary engineering at the University of California. By further transfers the Survey has been deprived of the services of three of the assistant chemists, Mr. Milford Everett Hinds, Mr. Wesley Wallace Hanford, and Mr. Henry Lawrence Huenink, and of two assistant engineers, Mr. Ralph Hilscher and Mr. Maurice Charles Sjoblom. Miss Madeleine Bixby, B.S., Tufts College, 1916, and Mr. Sidney Dale Kirkpatrick, B.S., University of Illinois, 1916, were appointed assistant chemists. Mr. Robert Edman Greenfield, A.B., University of Kansas, 1914, A.M., University of Illinois, 1916, was appointed assistant bacteriologist.

Instruction in the analysis and purification of water and sewage has been given by members of the Water Survey staff. There is one course for undergraduates, Chemistry 10, one course for graduates, Chemistry 110, and graduates and undergraduates registered in Chemistry 11 or Chemistry 111 may prepare theses on subjects connected with the chemistry of water and sewage. Many of the theses thus prepared have been published in the scientific and technical press and in bulletins of the State Water Survey.

The Water Survey has always occupied quarters in the Chemistry Building and from 1912 to 1916, used two additional rooms in the Engineering Hall. These were vacated in April, when new quarters in an addition to the Chemistry Building were ready for occupancy. The Survey now occupies thirteen rooms in the new addition and the former laboratories in the main part of the building are to be remodelled for instructional work in the chemistry of water and sewage.

LABORATORY WORK

From the time of its foundation, September, 1895, to December 31, 1916, 36,134 samples of water (see Table 1) have been received by the State Water Survey. Of these 22,415 were sent in by private citizens, health officers, or waterworks officials, and the others, including 2,800 collected in 1899 and 1900 in connection with the study of the Chicago Drainage Canal, have been collected either by members of the staff or under their direction for the study of special problems.

The greatest number of samples from one type of source, 8,753,

TABLE 1.—NUMBER OF WATER SAMPLES EXAMINED AT THE DIRECT REQUEST OF PRIVATE CITIZENS OR LOCAL HEALTH OFFICERS, CLASSIFIED BY YEARS AND BY SOURCE.

SOURCES.	October 1895, to Dec. 31 1896.	YEARS.																				Total from each source.
		1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	
Surface waters, rivers, lakes and ponds	69	72	102	54	59	61	97	75	80	107	304	330	356	372	428	196	393	640	599	577	715	5692
Springs	16	21	34	23	22	35	28	18	28	41	63	52	68	62	41	29	73	50	53	30	29	810
Cisterns	12	19	17	7	7	3	10	6	7	5	18	29	28	31	21	25	27	25	40	37	70	445
Natural ice	4	12	1	11	9	4	9	3	12	6	....	1	5	1	12	9	10	19	21	5	9	163
Artificial ice	....	1	....	2	1	....	1	1	1	....	4	....	....	0	0	1	0	....	2	12	7	33
Water for artificial ice	3	....	....	3	....	1	1	....	5	2	1	....	1	2	0	2	0	....	....	....	....	21
Water for natural ice	....	2	....	....	....	3	1	1	2	....	6	....	....	3	0	3	0	....	....	....	....	21
Mine water	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	11	10	4	5	35
Shallow wells in rock	28	16	8	22	12	22	10	17	25	25	19	45	32	53	43	29	31	20	11	8	....	476
Deep wells in rock	58	48	34	26	36	56	59	23	28	60	170	159	258	345	207	119	299	320	320	232	102	2971
Flowing wells in rock	45	8	16	12	13	14	3	8	9	11	22	17	43	3	2	2	9	6	....	....	....	243
Shallow wells in drift	500	245	108	243	274	209	243	245	270	292	442	514	683	614	344	256	436	435	563	622	1155	8753
Deep wells in drift	64	68	43	30	24	36	63	54	51	40	114	154	160	159	95	103	188	162	28	187	304	2007
Flowing wells in drift	63	5	4	9	4	....	3	5	5	12	19	25	2	1	7	....	....	....	....	....	....	164
Sewage	37	....	21	25	10	....	1	7	2	6	5	33	40	5	1	1	6	3	4	3	8	224
Distilled water	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	2	5	10	20
Miscellaneous	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	53	....	....	....	84	137
Unknown	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	30	72	2	10	....	134
Total samples from citizens	899	517	448	467	471	444	529	403	525	613	1182	1365	1682	1651	1201	795	1510	1756	1667	1732	2498	22415
Other samples	888	811	988	1579	1806	778	147	410	555	466	445	55	87	73	101	279	214	460	1105	1277	1120	13719
Total for year	1787	1328	1436	2046	2337	1222	676	882	1080	1079	1627	1420	1769	1724	1302	1074	1724	2216	2772	3009	3624	36134

has been taken from shallow wells in drift, naturally enough, since such wells furnish by far the greatest number of private supplies. Only 476 samples of water from shallow wells in rock have been received, undoubtedly because the greater part of the State is covered by 50 to 300 feet of glacial drift.

Deep wells in rock have furnished 2,971 and deep wells in drift 2,067 samples. Satisfactory water can be obtained from the deep wells in rock in the northern part of the State and from deep wells in drift in the east-central part of the State. Many surface waters (5,692) have been received because of the installation of filter plants and the additional monthly control tests which are made. The number of samples of ice has increased during the past three years, because of the requirements of the United States Public Health Service that all ice used by the railroads must be examined and approved before it can be used on railway trains.

TABLE 2.—NUMBER OF WATER SAMPLES EXAMINED DURING THE YEAR ENDING DEC. 31, 1916. CLASSIFIED BY MONTHS AND BY SOURCE.

Samples by request.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Surface waters, rivers, lakes, and ponds	41	51	64	29	51	79	44	72	82	70	58	74	715
Springs	1	0	1	1	6	2	4	6	3	4	1	0	29
Cisterns	4	1	3	3	8	4	6	8	17	10	5	1	70
Natural ice	0	0	0	3	2	0	2	0	1	1	0	0	9
Artificial ice	1	1	1	1	2	0	0	0	0	0	0	1	7
Deep wells in rock	8	3	12	6	13	7	10	7	6	11	12	7	102
Shallow wells in drift	39	59	66	19	58	147	237	97	157	147	83	46	1155
Deep wells in drift	4	9	15	10	21	54	35	33	34	30	31	28	304
Sewage	0	0	0	0	0	0	0	8	0	0	0	0	8
Distilled water	1	0	0	0	6	0	1	0	0	0	2	0	10
Mine water	0	0	0	0	1	2	0	2	0	0	0	0	5
Swimming pools	0	5	8	2	6	2	14	7	4	2	6	7	63
Boilers	0	0	2	0	4	0	6	4	2	0	1	2	21
Total	99	129	172	74	178	297	359	244	306	275	199	166	2498
MADE ON INITIATIVE OF WATER SURVEY.													
Surface waters, rivers, lakes, and ponds	0	0	0	4	0	1	0	6	7	0	0	6	24
Springs	2	0	0	0	0	0	0	0	0	0	0	0	2
Cisterns	0	0	3	0	0	0	1	0	0	8	0	0	12
Deep wells in rock	0	1	0	4	3	1	0	0	0	1	0	5	15
Shallow wells in drift	0	13	0	4	0	42	14	2	0	1	1	6	83
Deep wells in drift	0	3	0	0	1	8	2	3	14	10	1	3	45
Sewage	0	0	0	0	0	0	0	21	6	20	2	1	50
Special Swimming pools	0	0	0	0	0	0	0	0	0	0	32	0	32
University boilers	90	95	104	49	101	56	65	67	60	76	40	0	803
Microscopical examination	0	0	0	0	4	0	0	0	0	21	35	0	60
Total	92	112	107	61	109	108	82	99	87	137	111	21	1126
Grand total of samples by request and those on initiative of Water Survey	191	241	279	135	287	405	441	343	393	412	310	187	3624

During 1916, 3,624 samples of water were received. (See Table 2). The number in 1916 was greater than that in any other year since the foundation of the Survey, exceeding that received in 1915 by 20 per cent. The greatest number of samples was sent in during June, July, August, September, and October. During this period an average of more than 90 samples per week were received. For special study 803 samples were collected from the boilers of the University power plant and 60 samples were collected in connection with the microscopical survey of the reservoirs of the surface supplies of the State.

Well waters sent to the Survey for examination from 1907 to 1916 have been classified in Table 3 according to the depth of the wells.

TABLE 3.—PERCENTAGE OF WELL WATERS CONDEMNED BY THE WATER SURVEY CLASSIFIED BY DEPTH, 1907-1915.

	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	Tota
DEPTH LESS THAN 25 FEET											
Number examined	284	254	242	148	113	168	230	235	269	391	2334
Number condemned	240	192	183	118	74	113	155	189	176	291	1731
Percentage condemned	85	75	75	79	65	67	67	81	65	74	74
DEPTH 25 TO 50 FEET											
Number examined	224	395	354	201	196	353	262	331	391	544	3251
Number comdemned	173	250	226	137	122	185	166	206	236	343	2044
Percentage condemned	77	63	63	65	62	52	63	62	60	63	63
DEPTH 50 TO 100 FEET											
Number examined	111	192	161	90	89	129	164	158	239	270	1603
Number condemned	42	66	54	46	8	28	54	47	80	149	574
Percentage condemned	37	34	53	51	9	22	33	29	33	55	36
DEPTH MORE THAN 100 FEET											
Number examined	161	312	376	205	171	339	603	633	428	229	3457
Number condemned	22	31	62	43	30	49	59	51	65	46	458
Percentage condemned	13	9	16	20	17	14	10	8	15	20	14
DEPTH UNKNOWN											
Number examined	88	46	72	67	19	27	83	65	66	103	636
Number condemned	34	22	38	35	9	6	21	24	29	66	284
Percentage condemned	38	47	65	52	47	22	25	37	44	64	44
Total number examined	868	1199	1205	711	588	1016	1342	1422	1393	1537	11281
Total number condemned	511	561	563	379	243	381	455	517	586	895	5091
Percentage of total condemned	60	46	47	53	41	38	34	36	42	58	45

The number condemned decreases as the depth of the wells increases. Waters have been condemned from data afforded by the analyses and from information concerning the surroundings of the wells. The condemnation is not made because of the known presence of disease germs but rather because of the presence of filth and, therefore, the possibility of infection. During the ten years mentioned 74 per cent of the samples from wells less than 25 feet deep were condemned, whereas only 14 per cent of those from wells more than 100 feet deep were condemned. Many samples of water from the deepest wells were condemned not because of contamination but rather because of excessive mineral content. Of all well waters 45 per cent were condemned. The character of the water in the wells examined does not give a true idea of the character of all the well waters in the State, for by far the greater number of samples are sent in because of suspected contamination. In order to obtain a knowledge of the true condition of well water throughout the State analyses should be made of many representative samples collected from all parts of the State.

ENGINEERING WORK

During the past year members of the Engineering staff made investigations of existing and proposed water, supplies. As sewerage and water supplies are closely related, some investigations of sewerage were made. Three typhoid-fever epidemics were investigated to determine if the disease was spread by water supplies, and two examinations of stream pollution were made at the request of the Rivers and Lakes Commission. Conferences were held with local authorities regarding the construction of new water and sewer systems and the improvement of old ones. Reports describing water supplies, sewerage, and special investigations were made, as in previous years. Abstracts of reports may be found in Bulletins **9**, 15-33; **10**, 89-185; **11**, 28-141; **12**, 28-147; **13**, 30-143, and in this bulletin, pages 22 to 74. The work from 1912 to 1916 is briefly summarized in Table 4.

TABLE 4.—NUMBER OF ENGINEERING INVESTIGATIONS, CONFERENCES, INSPECTIONS, AND REPORTS PREPARED, 1912-1916.

Nature of work.	1912	1913	1914	1915	1916	Total
Inspections of public water supplies	60	101	101	117	52	431
Conferences concerning the installation and extension of public water supplies	1	59	34	19	20	133
Inspections of sewerage systems	25	28	34	20	4	111
Conferences concerning proposed sewerage systems	3	24	8	11	2	48
Special investigations	18	41	26	25	18	128
Reports prepared on public water supplies	60	85	82	96	46	369
Reports prepared on proposed water supplies and extensions	19	34	28	18	20	119
Reports prepared on sewerage systems	11	6	22	17	4	60
Reports prepared on proposed sewerage systems	14	10	5	11	2	42

There are 410 municipalities in the State with public water supplies. This includes 294, or 80 per cent, of the municipalities with more than 1000 population, and 116, or 17 per cent, of the municipalities with less than 1000 population. Of these municipalities, 327 are supplied with ground water, 62 are supplied with water from streams, and 21 are supplied with water from Lake Michigan. Special efforts have been made by the Survey to aid all municipalities with a population greater than 1000 in securing a public water supply of good quality. All surface water should be purified before being used for drinking purposes. For this reason the installation of purification plants has been promoted. At the end of 1916 forty-six public water supplies were being treated. Of these 36 were filtered for purification, 2 were treated by coagulation and sedimentation, and 3 were treated for iron removal. One city supply was softened and five were disinfected without other treatment. A list of the existing water supplies visited and described to the end of 1916, is given in Table 5. The waterworks of places whose names are printed in roman type are described in this bulletin and those of places whose names are printed in italic type have been described in preceding bulletins.

TABLE 5.—WATER SUPPLIES VISITED AND DESCRIBED BY THE ENGINEERING DIVISION, TO DEC. 31,1916.

Abingdon
Aledo
Alexis
Algonquin
Alpha
Alton
Amboy
Anna
Anna, State Hospital
Arcola
Arlington Heights
Arthur
Ashton
Assumption
Astoria
Atlanta
Aurora
Aviston
Avon
Barrington
Barry
Batavia
Beardstown
Belleville
Bellwood
Belvidere
Bement
Benson
Benton
Berwyn
Bloomington
Blue Island
Blue Mound
Braceville
Bradley
B raidwood
Breese
Brook field
Brookport
Buckley
Buda
Bureau
Bushnell
Byron
Cairo
Cambridge
Campus
Canton
Capron
Carbon Hill
Carbondale
Carlinville
Carlyle
Carmi
Carpentersville
Carrollton
Cary
Cedar Point
Central City
Centralia
Cerro Gordo
Chadwick
Charleston
Chatsworth
Chenoa
Cherry
Chester
Chicago Heights
Chillicothe
Cissna Park
Clinton
Coal City
Collinsville
Crescent City
Crete
Crystal Lake
Cuba
Cnllom
Danvers
Danville
Decatur
Deer Creek
Dekalb
D elavan
Depue
Des Plaines
Dixon
Downers Grove
Duquoin
Dwight
Earlville
East Dubuque
East Dundee
East Moline
East Peoria
East St. Louis
East Wenona
Edwardsville
Effingham
Elgin
Elgin, State Hospital
Elmhurst
Elmwood
El Paso
Eureka
E vanston
Fairbury
Fairfield

Farmer City
Farmington
Flora
Forest Park
Forrest
Forreston
Fort Sheridan
Freeburg
Freeport
Fulton
Galena
Galesburg
Galva
Geneseo
Geneva
Genoa
Gibson City
Gilman
Glencoe
Glen Ellyn
Glenview
Grand Ridge
Granite City
Granville
Grayville
Great Lakes, 77. S. Naval Training Station
Greenup
Greenview
Hamilton
Harmon
Harrisburg
Harvard
Harvey
Havana
Henry
Herrin
Highland Park
Hillsboro
Hinckley
Hinsdale
Hollywood
Homewood
Hoopeston
Ipava
Jacksonville
Jacksonville, Illinois School for the deaf
Jerseyville
Johnston City
Joliet
Joliet, Illinois State Penitentiary
Kankakee
Keithsburg
Kempton
Kenilworth
Kewanee
Eirkwood
Knoxville
Lacon
Ladd
LaGrange
LaGrange Park
La Harpe
Lake Bluff
Lake Forest
Lake Zurich
Lanark
La Salle
Lawrenceville
Leland
Lemont
Lena
Le Roy
Lewistown
Lexington
Libertyville
Lincoln
Lincoln, State School ana Colony
Litchfield
Little York
Lockport
London Mills
Lostant
Louisville
Lovington
Lyons
McHenry
McLeansboro
Mackinaw
Macomb
Manteno
Maple Park
Marengo
Marion
Mark
Maroa
Marseilles
Marshall
Mascoutah
Mason City
Matteson
Mattoon
Maywood
Melrose Park
Melvin
Menard, Southern Illinois Penitentiary
Mendota
Metamora
Metropolis
Milan
Milford
Milledgeville
Minier
Minonk
Mincoka
Mokena
Moline
Momence
Monee
Monmouth
Monticello
Morris
Morrison
Morrisonville
Morton
Morton Grove
Mound City
Mounds
Mount Carmel
Mount Carroll
Mount Morris
Mount Olive
Mount Pulaski
Mount Sterling
Mount Vernon
Moweaqua
Murphysboro
Naperville
Nauvoo
Newton
Nokomis
Normal
North Chicago
North Crystal Lake
Oakland
Odell
Ohio
Olney
Onargo
Oregon
Ottawa
Palatine
Pana
Paris
Paw Paw
Paxton
Pearl
Pearl City
Pecatonica
Pekin
Peoria
Peoria, State Hospital
Peotone
Peru
Petersburg
Pinckneyville
Piper City
Pittsfield
Plainfield
Piano
Polo
Pontiac
Portland
Princeton
Prophetstown
Quincy
Rantoul
Red Bud
River Forest

Riverdale
Riverside
Roanoke
Roberts
Robinson
Rochelle
Rock Falls
Rock Island
Rock Island, Arsenal
Rockdale
Rockford
Roodhouse
Rossville
Rushville
St. Anne
St. Charles
St. Elmo
Salem
San Jose
Sandwich
Savanna
Secor
Sheffield
Shelbyville
Sheldon
Silvis
Somonauk
Springfield
Spring Yalley
Stanford
Staunton
Steger
Sterling
Stockton
Stonington
Strawn
Streator
Sullivan
Summitt
Sycamore
Tampico
Taylorville
Thompson
Tiskilwa
Tolono
Toluca
Toulon
Tremont
Trenton
Tuscola
Utica
Walnut
Warren
Warsaw
Washington
Waterloo
Waterman
Watseka
Waukegan
Weldon
Wenona
West Brooklyn
West Chicago
West Dundee
West Hammond
Western Springs
Whitehall
Wilmette
Winchester
Winnetka
Woodstock
Wood River
Woodhull
Wyoming

The Engineering Division makes preliminary investigations and examination of local conditions in relation to proposed installations, improvements or additions to waterworks, filtration plants, sewerage, and sewage-treatment plants. The preliminary investigations and examinations of local conditions, in connection with new water-supply projects, forestall the selection of inadequate or unsuitable sources of supply and the installation of improper equipment.

Places that have been visited by members of the Engineering Division for the purpose of inspecting special conditions of water-works or sewerage or places for which plans of proposed waterworks or sewerage have been examined are named in Table 6. The names of places visited or for which plans were examined in 1916 are printed in roman type. The names of places visited or for which plans were examined during previous years are printed in italic type.

TABLE 6.—PLACES VISITED OR PLANS EXAMINED FOR PROPOSED INSTALLATIONS OR IMPROVEMENTS OF WATERWORKS OR SEWERAGE, TO DECEMBER 31, 1916.

Albion
Altamont
Alton
Anna
Anna, State Hospital
Arthur
Ashton
Assumption
Astoria
Atkinson
Aurora
Averyville
Harrington
Barry
Belleville
Bellwood
Benld
Benton
Bloomington
Blue Island
Bradley
Breese
Bunker Hill
Cairo

Camp Point
Canton
Carlyle
Carterville
Casey
Centralia
Charleston
Chester
Chrisman
Clinton
Colfax
Collinsville
Columbia
Great Springs
Crete
Cuba
Decatur
Deer Creek
Deland
Depue
Duquoin
East Peoria
Edwardsville
Effingham
Eldorado
Elgin
Elmhurst
Eureka
Evanston
Fairfield
Farmington
Flora
Galena
Galesburg
Geneseo
Geneva
Geneva, Illinois State Training School for Girls
Genoa
Georgetown
Gillespie
Girard
Glen Ellyn
Grand Ridge
Granite City
Grayslake
Greenville
Hamilton
Harmon
Harrisburg
Herrin
Heyworth
High Lake
Highland
Hillsboro
Jacksonville
Kansas
Keithsburg
Knoxville
La Moille
La Rose
Lawrenceville
Leaf River
Leland
Lincoln, State School ana Colony
Litchfield
McLean
Macon County Almshouse
Mansfield
Marion
Marissa
Matteson
Mattoon
Maywood
Melrose Park
Minonk
Moline
Monticello
Mound City
Mounds
Mount Pulaski
Mount Sterling
Mount Vernon
Neoga
New Athens
Nokomis
North Chicago
Oblong
Oglesby (See Portland)
Olney
Onargo
Palatine
Pana
Peoria Heights
Peoria, State Hospital
Petersburg
Piper City
Portland
Princeville
Rankin
Red Bud
Reddick
Roanoke
Roseville
Rushville
St. Anne
Salem
Sears
Sparta
Staunton
Stronghurst
Sullivan
Tinley Park
Tiskilwa
Toledo
Toulon
Troy
Tuscola
Villa Grove
Virden
Warsaw
Watseka, Iroquois County poor farm
Wenona
"West Frankfort
Westville
Wheaton
Whitehall
Winchester
Witt
Yorkville

SPECIAL INVESTIGATIONS

Special investigations were made of stream pollution, of the relation of water supplies to typhoid fever epidemics, and of special problems in water supply and sewerage. A microscopical survey of streams and impounded waters used for public water supplies was begun. The investigations made and reference to page on which abstracts of reports may be found are as follows:

Aurora, Alleged pollution of Indian Creek, (p. p. 23-25).
Centralia, Microscopical survey of reservoir. (p. p. 29-30).
Collinsville, Sewage disposal nuisance, (p. 31).

Danville, Microscopical survey of reservoir. (p. 32).

Decatur, Microscopical survey of reservoir. (p. 33).

Elgin, Elgin National Watch Co., Water supply and its relation to a typhoid-fever epidemic. (p. p. 35-39).

Elgin, Factory water supplies. (p. 35).

Hoopeston, Flooding cellars by sanitary sewage. (p. 42).

Hoopeston, Sewage disposal (Corn Canning Factory Wastes). (p. p. 42-44).

Illinois River, Examination of Illinois river between the cities of Morris and Peoria. (p. 44).

Lawrenceville, Pollution of Embarrass River and Indian Creek by oil. (p. p. 46-49).

Lincoln, State School & Colony, Investigation of dysentery and typhoid fever, (p. 50).

Mount Vernon, Microscopical survey of reservoir. (p. p. 54-55).

Mattoon, Microscopical survey of reservoir at Paradise, near Mattoon. (p. 52).

Odell, Test of operation of apparatus for removal of hydrogen sulfide from the water supply, (p. 56).

Pana, Typhoid-fever epidemic. (p. p. 57-59).

Peoria, Microscopical survey of reservoir. (p. 60).

Saint Peters, Typhoid-fever epidemic. (p. p. 63-64).

Sullivan, Masonic Home, Proposed improved water supply. (p. 66).

Waterloo, Microscopical and sanitary survey of reservoir. (p.p. 69-70).

Wenona, Water consumption and water waste. (p. 71).

SCIENTIFIC AND SPECIAL STUDIES

The routine analyses made in the laboratory of the Water Survey and inspections of private and municipal water supplies bring to the attention of the Water Survey many special problems relating to water, water supplies, sewage and sewerage. The members of the staff are, therefore, called upon to study special problems. The following summary indicates the special work which has been completed during 1916, the results of which are published elsewhere in this report. The regular staff has at times been assisted by instructors and graduate students in the University. Assistance in the preparation of material placed in this bulletin has been given by C. Scholl, C. W. Lenzing, W. F. Kamm, F. N. Crawford and W. R. Gelston.

The activated sludge method of sewage treatment. Strong sewage required more than 5 hours aeration and more than 1.5 cubic feet of air per gallon of sewage. The nitrogen in the sludge increases by from .4 to 1.5 per cent of nitrogen daily until an average of 5.1 per, cent of nitrogen is obtained. Excessive aeration decreases the total quantity of the sludge and the per cent of nitrogen in the sludge. The content of phosphorus pentoxide (P_2O_5) varies in the same way as nitrogen reaching an average of about 3 per cent. Centrifuges gave . promising results in dewatering sludge.

Radioactivity of Illinois waters. This study of ground waters with respect to radium emanation discovers some springs in this State whose radioactivity equals that of waters for which medicinal value is claimed.

Effect of gas house waste on biochemical oxidation of sewage. It is shown that certain waste liquors from the manufacture of illuminating gas have little or no effect upon the biological purification of sewage.

Decomposition products of sewage disposal. This paper presents a study of the effluent gases from activated sludge treatment: an increment of carbon dioxide during aeration is derived from biological fermentation.

Bacterial purification of sewage. A discussion of phases of sewage purification not always discriminated: namely, the existence of cycles of nitrifying and of denitrifying organisms, both of which are essential to sewage purification by the activated sludge method.

Operating results from the new purification plant at Quincy, Ill. The old filtration plant at Quincy was one of the pioneer plants in Illinois; the new one embodies the most recent improvements.

ABSTRACTS OF ENGINEERING REPORTS

The following pages contain abstracts of detailed reports of various investigations made by the Engineering Division during 1915 and references by number and page to abstracts of reports made prior to 1915 and printed in preceding bulletins of the State Water Survey. These abstracts are arranged in alphabetical order by name of city, village, or town. Eeferences to abstracts in previous reports are given in parentheses after the title of each investigation. Capacities of pumps, yields of wells, and consumptions of water are stated in gallons per 24 hours unless otherwise specified. Depths of wells are given in feet from the surface of the ground unless otherwise specified. It should be understood that estimates of capacity, yield, daily consumption, consumption per capita, discharge of sewage, and similar amounts are rounded off to avoid expression of fictitious accuracy.

ABINGDON. Water supply.—(Bull. **11**, 28.)

ALBION. Proposed water supply.—(Bull. **10**, 89.)

ALEDO. Sewage disposal.—(Bull. **10**, 90; **13**, 30.)

ALEXIS. Water supply.—(Bull. **13**, 30.)

ALGONQUIN. Water supply.—(Bull. **13**, 30.)
Sewerage.—(Bull. **13**, 31.)

ALPHA (358). Water supply.—Visited October 9. Alpha is in the southwestern part of Henry County. There are no sewers in the village.

Waterworks were installed in 1908. The supply was obtained from a well 1465 feet deep, leased from the Chicago, Burlington, and Quincy Railroad Co. Water is pumped from the well into the distribution system by an electrically driven deep-well pump with automatic control. A gasoline engine furnishes power in case of emergency. The distribution system includes about two miles of mains, 18 fire hydrants and 5 valves. A 6,000-gallon wooden tank on a 50-foot steel tower is connected with the distribution system. There are 85 services of which 81 are metered. The daily consumption is about 6,000 gallons. The waterworks cost about $7,000, operating expenses are about $400 and the annual income is about $500.

The water is of good sanitary quality. It has a mineral content of 1017, a total hardness of 215, and a content of iron of 0.2 parts per million.

ALTAMONT. Proposed water supply.—(Bull. **11**, 28.)

ALTON. Water supply.—(Bull. **9**, 15; **10**, 90; **11**, 29; **12**, 28; **13**, 31.)
Proposed additional sewers.—(Bull. **12**, 30.)
Nuisance complaint.—(Bull. **12**, 30.)

AMBOY. Water supply.—(Bull. **11**, 29.)

ANNA. Water supply.—(Bull. **9**, 15; **11**, 30.)
Sewerage.—(Bull. **9**, 15; **11**, 30.)

ANNA, State Hospital. Water supply.—(Bull. **9**, 15; **10**, 91; **12**, 30; **13**, 31.)
Proposed sewage treatment.—(Bull. **12**, 32.)

ARCOLA. Water supply.—(Bull. **10**, 91.)

ARLINGTON HEIGHTS. Water supply.—(Bull. **12**, 32.)
Swage disposal.—(Bull. **10**, 91; **12**, 32; **13**, 31.)

ARTHUR. Water supply.—(Bull. **10**, 94; **12**, 33.)

ASHLEY. Public wells.—(Bull. **13**, 32.)

ASHTON. Water supply.—(Bull. **13**, 32.)
Sewage-treatment plant.—(Bull. **13**, 33.)

ASSUMPTION. Water supply.—(Bull. **11**, 31; **12**, 33.)
Sewerage.—(Bull. **11**, 32.)

ASTORIA. Water supply.—(Bull. **11**, 32.)

ATKINSON. Proposed water supply.—(Bull. **13**, 33.)

ATLANTA. Water supply.—(Bull. **11**, 33.)

AURORA. Water supply.—(Bull. **9**, 16; **11**, 34; **12**, 33.)

AURORA. Alleged pollution of Indian Creek.—At the request of the Rivers and Lakes Commission an investigation was made of alleged pollutions of Indian Creek by industrial wastes. Inspections were made on March 27 and 31, July 31, and August 1.

Indian Creek, a small stream, rising northeast of Aurora, flows southward into the northeastern part of the city and then flows westward along the right-of-way of and through the shop grounds of the Chicago, Burlington & Quincy

Railroad Co. to Fox River. Wastes are discharged into the creek from the plant of the Monroe Binder Board Co. Waste from the Commercial Acetylene Railroad Light and Signal Co. and the Western Wheeled Scraper Works are discharged into a small tributary about 200 feet above its outlet into Indian Creek. This tributary discharges into the creek just below, the outlet of the sewer from the Monroe Binder Board Co.

The Monroe Binder Board Co. manufactures cardboard, using principally, waste paper and cardboard. The waste paper is ground and churned to form a pulp. Lamp black is added to color the product and alum is added to give it greater compactness. The pulp is pressed and dried into sheets of cardboard. Large quantities of water are used to reduce the waste paper to pulp, to transport the pulp, and to wash rolls and screens of the cardboard machines. About 300,000 gallons of water carrying paper pulp, lamp black, and alum are discharged from the plant each day. This waste was discharged directly into Indian Creek until in 1913 when a large settling tank was built. In January 1916 a machine called a Pneumatic Save-All was installed to filter the waste before it passed to the settling tank. It consists of a cylindrical screen of No. 80 mesh wire which allows water to escape and strains out the pulp which is blown off from the screen by air and returned to the pulp tank. The settling tank is 160 feet long, 40 feet wide and 7 feet deep. The wastes enter at one corner, flow diagonally across the tank and are discharged through a tile into Indian Creek. The tank is not covered and is not baffled. Deposited material is drawn off through openings in the bottom of the tank and mixed with the pulp. The waste has a characteristic odor of paper-mill waste and is very dark colored and turbid. Sewage from this plant is also discharged into the creek.

The Commercial Acetylene Railroad Light and Signal Co. daily uses about 4,000 gallons of water to treat about 6,000 pounds of carbide and about 22,000 gallons of water for cooling purposes. The waste water carrying lime resulting from the treating of the carbide is discharged into either of two concrete settling tanks each 100 feet long, 40 feet wide and 8 feet deep with a capacity of 240,000 gallons. The effluent from the tanks passes over weirs into a drain leading to the creek. The suspended matter settles and when one tank is practically full it is cleaned and the waste is passed into the other tank. Some material cleaned from the tanks is washed into the stream at times of rains.

The Western Wheeled Scraper Works manufactures scrapers and other equipment used on construction work. Liquid wastes, estimated at 40,000 gallons a day, are discharged from boiler rooms, washrooms and toilets of this plant. A considerable quantity of oil is also discharged into the creek.

On March 27 and 31 Indian Creek was high and the dilution afforded the wastes was sufficient to prevent any nuisance downstream.

On July 31 and August 1 there was no flow in the creek above the factories. Below the binder board plant the creek did not have an objectionable odor but was unsightly in appearance and large patches of dark scum covered the surface at places where there was little current. The presence of sewage was not noticeable. At the outlet of the sewer from the Western Wheeled Scraper Works, however, the presence of sewage was noticeable and sludge deposits were observed along the banks. The condition of the stream was not objectionable at the point of discharge into Indian Creek about 200 feet distant. The oil waste was unsightly and no doubt hindered the aeration of the creek waters. There was practically no waste from the acetylene plant at the time of the inspections but it is reported that considerable waste is discharged from this plant at times and gives the creek a milky appearance because of the lime carried in suspension.

From the point of entrance of the wastes to the shops of the Chicago, Burlington, and Quincy Railroad Co. near the mouth of the creek the appearance is practically the same. Septic action was noticeable at a few points in stagnant pools. The odor increased downstream but was not very disagreeable at any place. Oil on the surface was noticeable for several thousand feet down stream.

Samples of the wastes from the Monroe Binder Board Co., from the Western Wheel Scraper AVorks, and from the settling basin of the Commercial Acetylene Railway Light and Signal Co. and samples of the creek water from three points along its course were collected and analyzed in the laboratory.

The waste from the Binder Board Co. had a residue of about 1200 parts per million. Analyses of one sample showed 281 parts per million of suspended solids and an oxygen-consuming capacity of 140 parts per million. The other sample contained 60 parts per million of suspended solids and had an oxygen-consuming capacity of 83 parts per million. The waste is putrescible but much less so than domestic sewage. The waste from the Western Wheeled Scraper Works was similar to dilute domestic sewage, except that it contained considerable oil. The waste from the acetylene plant is non-putrescible and the only objection to it is that it would give color to a stream and would form sludge deposits. Analyses of a sample collected just below the entrance of all three wastes and one collected a half mile further downstream indicated little improvement.

A few experiments were made by mixing waste from the settling basin of the acetylene plant with waste from the binder-board plant. In a mixture of 1 to 1 and in other mixtures as dilute as 1 to 16 a precipitate formed and settled rapidly giving a clear supernatant liquid which became slightly milky on standing, probably due to action of carbon dioxide on the lime. A solution of alum applied to binder-board waste gave a precipitate and a clear liquid but the action was much slower than with lime.

The waste from the Monroe Binder Board Co. is an objectionable waste to be discharged into Indian Creek especially at times of low flow because of its physical appearance rather than its putrescibility or toxic effect. It could probably be satisfactorily treated with chemicals. The drainage from the toilets of the manufacturing plants is putrescible but if oily wastes are eliminated the dilution afforded by the binder-board waste may be sufficient to prevent a nuisance down the stream. If objectionable conditions exist after treatment of the binder-board and oily wastes then the treatment of the sewage can be considered. The waste from the acetylene plant is not very objectionable and should not give rise to complaints if the settling basins are properly operated.

AVERYVILLE. Proposed sewerage.—(Bull. **12**, 34.)

AVISTON. Copper-sulfate treatment of reservoir.—(Bull. **11**, 34.)

AVON. Water supply.—(Bull. **13**, 33.)

BARRINGTON. Water supply.—(Bull. **12**, 34.)
Proposed sewerage.—(Bull. **10**, 94.)

BARRY. Water supply.—(Bull. **12**, 35.)

BATAVIA. Water supply.—(Bull. **9**, 16.)

. BEARDSTOWN. Water supply.—(Bull. **11**, 35.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **11**, 35.)

BELLEVILLE. Water supply.—(Bull. **11**, 36.)
Sewage disposal.—(Bull. **12**, 35; **13**, 34.)

BELLWOOD. Water supply.—(Bull. **12**, 36.)

BELVIDERE. Water supply.—(Bull. **11**, 36.)
Alleged pollution at Kishwaukee River by gas-house wastes.—(Bull. **11**, 36; **13**, 34.)

BEMENT. Water supply.—(Bull. **10**, 95.)

BENLD. Proposed water supply.—(Bull. **12**, 36.)

BENSON. Water supply.—(Bull. **13**, 35.)

BENTON. Proposed improvement of water supply.—(Bull. **9**, 16; **10**, 95; **11**, 38; **12**, 36.)
Sewage treatment.—(Bull. **10**, 96; **12**, 37.)

BERWYN. Water supply.—(Bull. **13**, 35.)

BLOOMINGTON (25,768). Water supply.—(Bull. **10**, 96; **12**, 37.) Visited February 1 and February 8. An additional well known as well No. 4 similar to the three original wells was put in operation in 1914. The well has a concrete shaft 25 feet in diameter and about 30 feet deep, lined with concrete and water-proofed throughout. Through the bottom of the shaft eight 10-inch tubular wells extend to a further depth of 30 feet. Each is equipped with 10-ineh No. 20 Cook well screen 20 feet long. These tubular wells are connected to the suction of a centrifugal pump of 1500 to 2000 gallons a minute capacity sot on the floor of the shaft. This pump is driven through a vertical shaft by a 50-horsepower electric motor enclosed in a small brick building. Water Stands about 35 feet below the surface when not being pumped. This well has been delivering about 2,000,000 gallons a day. A rotary pump has replaced the centrifugal pump formerly used, in well No. 2.

BLUE ISLAND. Water supply.—(Bull. **12**, 37; **13**, 37.)
Pollution of Stony Creek and Calumet Lake.—(Bull. **13**, 37.)

BLUE MOUND. Water supply.—(Bull. **12**, 38.)

BRACEVILLE. Water supply.—(Bull. **12**, 39.)

BRADLEY (1,924). Water supply.—Visited November 27. Bradley is an industrial community in the central part of Kankakee County on the drainage area of Kankakee River about 1¾ miles north of the center of Kankakee. Objections to a proposed sewer system are being considered by the courts.

Waterworks were installed in 1905. The source of supply is a well 12 inches in diameter and 332 feet deep. The static water level is at a depth of 30 feet. Water is pumped from the well into the distribution system by an electrically driven double-acting deep-well pump. A gasoline engine is used to furnish power in cases of emergency. The distribution, system includes about 3,100 feet of 8-inch and 13,400 feet of 4-inch mains and 36 hydrants. An elevated steel tank 52 feet high and 13 feet in diameter on a 68-foot brick tower is connected to the distribution system.

In addition to the water supply described above there is a water main connected to the Kankakee water-distribution system on one street in Bradley from which, a few residences and one factory secure filtered Kankakee Eiver water.

The water from the municipal supply and that from the Kankakee supply are of good sanitary quality. The municipal supply has a total mineral content of 525, a total hardness of 365, and a content of iron of 0.1 parts per million.

BEADLEY. Proposed sewerage.—(Bull. **11**, 38.)

BEAIDWOOD. Water supply.—(Bull. **12**, 39.)

BEEESE. Water supply.—(Bull. **9**, 16; **11**, 39; **12**, 40; **13**, 38.)

BROOKFIELD. Water supply.—(Bull. **13**, 38.)

BEOOKPOET. Water supply.—(Bull. **11**, 40; **13**, 38.)

BUCKLEY. Water supply.—(Bull. **13**, 39.)

BUDA. Water supply.—(Bull. **13**, 40.)

BUNKER HILL. Proposed water supply.—(Bull. **13**, 40.)

BUEEAU. Water supply.—(Bull. **13**, 41.)

BUSHNELL. Water supply.—(Bull. **12**, 40.)
Sewerage.—(Bull. **9**, 17; **12**, 41.)

BYEON. Water supply.—(Bull. **11**, 40.)

CAIRO. Water supply.—(Bull. **10**, 96; **11**, 40; **12**, 42; **13**, 41.)

CAMBRIDGE. Water supply.—(Bull. **10**, 96.)

CAMP POINT. Proposed water supply.—(Bull. **11**, 41.)

CAMPUS (241). Water supply.—Visited November 15. Campus is in the northeastern part of Livingston County on the drainage area of Mazon Creek. The streets are well drained with tile drains. Wastes from many residences flow through cesspools and sewage tanks into these drains.

Waterworks were installed about 20 years ago. Water was pumped from a 2-inch well into an elevated tank by a pump! operated by a wind mill. The present source of supply is a well 130 feet deep in glacial drift. Water is pumped from the well into the distribution system by a 5¾-inch by 24-inch deep-well pump driven by a 25-horsepower kerosene engine. The distribution system includes about 1.1 miles of mains, 16 fire hydrants, and 49 service connections. An elevated steel tank 12 feet in diameter and 30 feet high on a 50-foot brick tower is connected to the distribution system. The public water supply is used by nearly all residents. The consumption is estimated to be about 21,200 gallons a day.

The water is of good sanitary quality. It has a mineral content of 686, a total hardness of 216, and a content of iron of 0.4 parts per million.

CANTON. Proposed improved water supply.—(Bull. **11**, 41; **12**, 43.)
Sewage-disposal nuisance.—(Bull. **9**, 17.)

CAPEON (562). Water supply.—Visited September 8. Capron is an agricultural community in the northeastern part of Boone County on the drainage area of Kishwaukee River, a tributary of Eock Eiver. Tile drains carry wastes from kitchen sinks, seepage and overflow from cesspools. There are no sewers.

. Waterworks were installed in 1900. The source of supply is a well 680 feet deep. The upper 400 feet is in drift and is eased part with 8-inch and part with 6-inch pipe. The lower part of the well is 5 inches in diameter. In 1900 the static water level was 10 feet below the top of the well and it has since been lowered 5 feet. Water is pumped from the well into the distribution system by a single acting pump with a 4¾-inch by 24-inch cylinder placed at a depth of 50 feet. Four feet of suction pipe is attached to the cylinder. With a pump displacement of 70 gallons a minute the water level is not drawn down to the bottom of the suction pipe. The pump is driven by a belt from a 10-horsepower gasoline engine. The distribution system includes 1.3 miles of mains from 4 inches to 10 inches in diameter, 14 hydrants, 6 valves and 99 service connections. The mains are laid 6 feet deep. Galvanized iron service pipe is used. A 30,000-gallon cypress tank on an 80-foot brick tower is connected to the distribution system. The average daily consumption is estimated to be about 10,000 gallons.

The water is of satisfactory sanitary quality. It has a mineral content of 362, a hardness of 335, and a content of iron of 1.3 parts per million.

CARBON HILL. Water supply.—(Bull. **12**, 44.)

CAEBONDALE. Water supply.—(Bull. **11**, 42.)

CAELTNVILLE. Water purification.—(Bull. **10**, 97; **12**, 44.)

CAELYLE. Proposed water-purification plant.—(Bull. **9**, 17; **11**, 43; **13**,41.)

Sewerage.—(Bull. **12**, 45.)

CAEMI. Water supply.—(Bull. **11**, 44.)

CAEPENTEBSVILLE. Water supply.—(Bull **11**, 42.)

CAEEOLLTON. Water supply.—(Bull. **11**, 44.)

CABTEEVILLE. Proposed water supply.—(Bull. **12**, 45.)

CAETHAGE. Sewage disposal.—(Bull. **10**, 99.)

CAEY (679). Water supply.—Visited September 7. Cary is an agricultural community in the southeastern part of McHenry County about one mile from Fox Eiver.

Waterworks were installed in 1913. The source of supply is a 10-inch well 300 feet deep. The upper 154 feet is in drift and is cased. The lower 146 feet is in limestone. The static water level is normally at a depth of 12 feet. When the pump is operated at the rate of 110 gallons a minute the water level is drawn down to the pump cylinder at a depth of 80 feet. Water is pumped from the well into a concrete reservoir by a deep-well pump with a capacity of 85 gallons a minute. The reservoir is of 100,000 gallons capacity. It is built of reinforced concrete and the top is 11 feet above the ground surface. Water is pumped from the reservoir into the distribution system by two electrically driven 460,000-gallon centrifugal pumps. They can be operated in parallel or in series and each is equipped with an automatic device which starts the pump when the pressure falls to 28 pounds and stops it when the pressure reaches 38 pounds. Generally one pump is in service about 1 to 1½ hours a day. This indicates a daily consumption of about 25,000 gallons. The distribution system includes about 2½ miles of 4-inch, 6-inch and 8-inch cast-iron pipe, 36 fire hydrants, and 30 service connections. All services are metered but the meters are not read. A 70,000-gallon reinforced-concrete standpipe located on a hill is connected to the distribution system. The waterworks cost about $24,000.

The water is of good sanitary quality. It has a mineral content of 341, a hardness of 245, and a content of iron of 0.8 parts per million.

CASEY (2,157). Proposed improved water supply.—(Bull. **10**, 100; **13**, 43.) Visited October 2 and 3 to assist with tests on wells proposed as a source of public water supply. The city has drilled two wells in the bottom lands of North Fork of Embarrass Eiver about five miles east of Casey. They are fifteen feet apart. Both are 8 inches in diameter and are provided with No. 40 Cook screens 12 feet long. One well is 80 and the other is 131 feet deep. Sand and gravel yielding considerable water was encountered between depths of 47 feet and 80 feet and between depths of 117 and 131 feet. In wells drilled for oil in the bottom land, water-bearing strata were penetrated and the strata are known to extend from five miles upstream to 11 miles downstream from the location of the new city wells.

In the shallower city well the static water level is at a depth of about 18 inches and in the deeper well it is at a depth of about 9 feet. Both wells yield gas, the larger yield being from the deeper well. The shallower well was pumped for 68 hours, at rates of from 147 to 227 gallons a minute, without drawing air into the pump cylinder which is placed at a depth of 69 feet. The deeper well was pumped for 53 hours at a rate of about 125 to 130 gallons a minute. Pumping one well did not affect the water level in the other well.

The wells are 1½ miles from a railroad. The relative costs of operation with steam-driven and electrically-driven pumps and the relative advantages of having a reservoir close to the wells or in the city should be considered. The reservoir in the city would give a reserve supply in case of accident to the force main. A reservoir near the wells would be of advantage in allowing gas to escape and in reducing the content of iron. The wells should be suitably protected against contamination at times of overflow of the bottom lands. A consulting engineer has not been employed.

Water from the shallower well has a mineral content of 542, a hardness of 294, and a content of iron of 4 parts per million. Water from the deeper well has a total mineral content of 1020 parts per million of which 780 parts are sodium chloride and sodium carbonate. It has a hardness of 206 and a content of iron of 4 parts per million. Water from a 50-foot test well in the bottom land of Embarrass River, 10½ miles southwesterly from Casey, has a mineral content of 341, a hardness of 284, and a content of iron of 1.0 parts per million.

CEDAR POINT. Water supply.—(Bull. **11**, 45.)

CENTRAL CITY (1,179). Water supply.—Visited September 22. Central City is in Marion County, north of and adjoining the city of Centralia. The water supply is obtained from Centralia. The Centralia pumping station is loeated north of Central City. A 12-inch main carries water from the pumping station through Central City to Centralia. A 400-foot branch line of 2-inch pipe has been laid. There is one fire hydrant in the village and 25 service connections are in use.

CENTRALIA. Microscopical survey of reservoir.—Visited October 28. The water supply is obtained from a 950,000,000-gallon impounding reservoir located about 8 miles northeast of the city. This reservoir covers approximately 264 acres, 46 acres of which are covered with water to a depth of 5 feet or less. The maximum depth is about 24 feet. The drainage area is about 8 square miles, the greater part of which is either under cultivation or is covered by small patches of woodland. In general the banks of the reservoir are of clay and are abrupt, rather than sloping. In three or four places swampy areas were noted near the edge of the water. In the upper portion of the reservoir there are a large number of stumps, some of which are entirely covered by the water. Many of these stumps have moss growths clinging to them. It would be desirable to remove the growing vegetation near the edge of the water and any decaying stumps since such material offers a favorable environment for the growth of algae. The possible sources of pollution include about a dozen farm houses and two cemeteries. Picnic parties are allowed along the bank at some points but it was said that bathing, boating and swimming in the reservoir are prohibited.

The water was in excellent physical condition except for the presence of finely divided clay in suspension. Microscopic examinations of samples of the water showed very small numbers of organisms capable of producing tastes or odors. Since small numbers of odor-producing types of organisms were found it is possible that under favorable conditions troublesome microscopic growths might occur but ordinarily these growths would occur only in small bayous or in small portions of the lake. The water contained an adequate supply of dissolved oxygen in all of the samples tested ranging from 80 per cent to 98 per cent saturation.

It was stated that the calcium hypochlorite-treatment plant was not used at all times. The plant should be put in operation pending the erection of a mechanical filtration plant.

Should odors or tastes develop in the water in the reservoir copper sulphate should be added to the parts showing algae growths, in sufficient quantity, to kill the particular organism causing annoyance.

CENTEALIA (9,680). Water supply.—(Bull. **10**, 102; **11**, 45; **12**, 46; **13**, 43.) Visited September 22. All parts of the waterworks were in good working order and no important changes have been made recently. The length of concrete pavement below the spillway of the reservoir was being increased to prevent erosion of dirt during floods. The most needed improvement is the installation of a filtration plant.

CENTEALIA. Sewerage.—(Bull. **10**, 102; **12**, 46.)

CEEEO GORDO. Water supply.—(Bull. **12**, 46.)

CHADWICK. Water supply.—(Bull. **11**, 46.)

CHAELESTON. Water supply.—(Bull. **10**, 103; **11**, 46; **12**, 47; **13**, 43.)

CHATSWORTH (1,112). Water supply.—(Bull. **9**, 17.) Visited November 16. Chatsworth is in the southeastern part of Livingston County on the drainage area of Vermilion Eiver. Plans were prepared and an ordinance passed[1] in 1915 providing for the installation of a combined system of sewers with two outlets into ditches which are dry through most of the year. The sewers have not been built. The method of disposal would not have been satisfactory.

Waterworks were installed in 1909. The source of supply is a well 1285 feet deep terminating in St. Peter sandstone. The top of the well is in a pit about four feet deep. Water is pumped from the well into a concrete reservoir by an 8-inch by 30-inch deep well pump. The reservoir is 34 feet in diameter and 12 feet deep with a capacity of about 80,000 gallons. It is covered with a conical roof of corrugated galvanized iron. An 8-inch by 10-inch triplex pressure pump draws water from the reservoir and discharges into two steel pressure tanks 9 feet in diameter and 36 feet long, which rest on the pumping station floor. Power to run the pumps and a small air compressor is furnished by either one of two 25-horsepower gasoline engines. The distribution system is connected with the pressure tanks. There are about 160 service connections.

An analysis of the water indicated that the supply was receiving some contamination. It is likely that this enters the surface reservoir through the roof or it may occur through seepage into the well from the well pit. The water has a mineral content of 567, a total hardness of 278, and a content of iron of 0.5 parts per million.

CHENOA. Water supply.—(Bull. **9**, 17; **12**, 48.)

CHEERY. Water supply.—(Bull. **13**, 43.)

CHESTER. Water supply.—(Bull. **9**, 18; **11**, 47.)

CHICAGO HEIGHTS. Water supply.—(Bull. **11**, 47.)
Sewerage.—(Bull. **11**, 48.)

CHILLICOTHE. Water supply.—(Bull. **12**, 49.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 19; **11**, 50.)

CHRISMAN. Proposed sewerage.—(Bull. **11**, 50; **13**, 44.)

CISSNA PARK. Water supply.—(Bull. **13**, 44.)

CLINTON. Contamination of water supply.—(Bull. **12**, 50.)

COAL CITY. Water supply.—(Bull. **12**, 50.)

COLFAX. Proposed sewerage.—(Bull. **11**, 51.)

COLLINSVILLE. Water supply.—(Bull. **10**, 104.)
Typhoid fever.—(Bull. **12**, 51.)

COLLINSVILLE (7,478). Sewage disposal.—(Bull. **10**, 104; **11**, 51; **12**, 50; **13**, 45.) Collinsville was visited August 17 to confer with the city council relative to the pollution of a water course by the sewage of the city.

The discharge of sewage from Collinsville into two small tributaries of Cahokia Creek has caused objectionable conditions. Previous suggestions and recommendations of the Survey for improving conditions have not been adopted. On September 14, 1915 the Rivers and Lakes Commission dismissed a complaint filed against the city and called attention to the desirability of operating the septic tanks of the city so that no offense would develop. The city has not complied with the intent of that order and is again being sued.. The tank for sewage district No. 1, which includes the central and northern sections of the city, had not been cleaned for presumably at least two years and was providing little or no sedimentation. The effluent was being made more objectionable by the addition of septic sludge. The city officials are considering the purchase of land on either side of the stream where the nuisance exists in order to relieve the city of paying damages.

COLUMBIA (2,076). Proposed water supply.—(Bull. **10**, 105; **11**, 51; **12**, 51; **13**, 46.) Visited August 17. A bond issue to cover part of the cost of the installation of waterworks was defeated by popular vote on June 12, 1915. The water distribution system and a sewer system were to have been paid for by special assessments. The total estimated cost of the waterworks and sewerage was about $50,000. The installation of waterworks alone may possibly be considered in the future.

COLUMBIA. Proposed sewerage and sewage treatment.—(Bull. **13**, 46.)

COOK, County poor farm. Sewage disposal.—(Bull. **11**, 52.)

CREAL SPRINGS. Water-supply conditions.—(Bull. **11**, 52.)

CRESENT CITY. Water supply.—(Bull. **13**, 47.)

CRETE. Water supply.—(Bull. **13**, 48.)
Proposed sewerage.—(Bull. **13**, 48.)

CRYSTAL LAKE. Water supply.—(Bull. **9**, 19; **11**, 52.)
Typhoid fever.—(Bull. **9**, 19.)

CUBA. Water supply.—(Bull. **12**, 51; **13**, 48.)
Proposed sewerage.—(Bull. **13**, 49.)

CULLOM (579). Water supply.—Visited November 16. Cullom is in the central eastern part of Livingston County on the drainage area of Vermilion River. There are no sewers in the village.

A well was drilled, a gasoline engine and a deep-well pump installed, and an elevated tank erected in 1906. A distribution system was built in 1907. The present source of supply is a well 10 inches in diameter at the top and about 1700 feet deep. It penetrates St. Peter sandstone between the depths of 1280 and 1470 feet. No records of strata below this depth are available. The static water level is at a depth of 70 feet. Water is pumped from the well into the distribution system by a deep-well pump with a 2¼-inch by 24-inch cylinder 200 feet below the surface. The pump is driven by a 16-horsepower gasoline engine. The distribution system includes' about 2.29 miles of water mains, 26 fire hydrants, and 60 service connections. An elevated steel tank is connected to the distribution system.

The water is of good sanitary quality. It has a mineral content of 1.011, a hardness of 76, and a content of iron of 0.5 parts per million.

DANVERS. Water supply.—(Bull. **12**, 51; **13**, 50.)

DANVILLE. Water supply.—(Bull. **9**, 19; **12**, 52.)

DANVILLE. Microscopical survey of reservoir.—Visited September 18, to investigate the microscopic and sanitary conditions of a new 400,000,000-gallon impounding reservoir on the north fork of Vermilion River located about 4 miles above the pumping station. A considerable area of farm land and woodland and a small area of swampy land has been inundated in order to build this reservoir. Most of the trees and large brush have been removed from this area but seemingly no attempt has been made to remove stumps and small vegetation.

As might be expected from cold weather conditions previous to the time of the visit the water in the reservoir was in good condition. In most places the water had a greenish tint excepting near the mouth of Leseure Ravine where it had a decidedly muddy color. Floating masses of filamentous algae were seen at a few points. Samples of water were collected and examined microscopically and for dissolved oxygen. Protozoan forms, rotifers and chlorophyceae were numerous. Of the chlorophyceae the most numerous type was protococcus. None of these were present in large enough quantities to make treatment advisable. The dissolved oxygen ranged from 61 per cent to 92 per cent saturation on the surface and 45 per cent to 70 per cent saturation near the bottom of the reservoir.

No serious trouble from odor and no difficulty in filter operation need be anticipated from the number of organisms present. It seems possible during extended periods of warm weather that the decay of vegetable matter in the reservoir may give rise to extensive growths of micro-organisms that would cause annoyance but no treatment of the reservoir seemed necessary at that time.

DECATUR. Water supply.—(Bull. **10**, 106; **11**, 53; **12**, 55; **13**, 51.)
Sewage disposal.—(Bull. **10**, 107; **11**, 253; **12**, 55.)

DECATUR. Microscopical survey of reservoir.—Visited October 6. Decatur is furnished with water from a reservoir which was formed by constructing a dam across Sangamon Eiver. The water is filtered and treated with hypochlorite before it is used. At the time of inspection the water level in the reservoir was several feet below the crest of the dam. The banks for the most part are either mud or sod with trees growing to the water edge in some places. The water was quite muddy and the surface was partly covered with a scum having an oily appearance. Floating masses of filamentous algae were seen at all of the parts visited. Non-filamentous micro-organisms were found to the extent of about 300 per cc. Of these some are of known odor-producing power noticeably dinobryon and uroglena. It was very noticeable that the predominating micro-organisms were of the animal types. This would indicate that the reservoir was becoming nearly stagnant. Dissolved oxygen samples collected from the bottom showed a content of from 35 to 47 per cent of saturation indicating a condition approaching stagnation. Samples from the surface showed dissolved oxygen of from 111 to 117 per cent of saturation. The results of the investigation showed that the reservoir at the time of the visit did not need chemical treatment. However, if at any time the conditions become much worse, serious odors and tastes would develop. In such an event treatment with copper sulfate would help.

DEER CREEK (332). Water supply—.(Bull. **10**, 107; **11**, 53.) Visited December 14. At the time of visit there were 29 service connections in use and the daily consumption was estimated to be about 1800 gallons a day.

One analysis indicated slight contamination. It was recommended that the surroundings be carefully examined and that necessary changes be made if any surface drainage enters the well. The water has a mineral content of 373, a total hardness of 351, and a content of iron of 0.3 parts per million.

DEKALB. Water supply.—(Bull. **13**, 56.)
Sewage disposal.—(Bull. **13**, 57.)
Pollution of Kiswaukee River.—(Bull. **13**, 57.)

DELAND. Proposed water supply.—(Bull. **12**, 55; **13**, 58.)

DELAVAN. Water supply.—(Bull. **12**, 56.)

DEPUE. Water supply.—(Bull. **13**, 59.)
Proposed sewerage.—(Bull. **13**, 59.)

DESPLAINS. Water supply.—(Bull. **13**, 60.)
Sewerage.—(Bull. **10**, 66; **11**, 54; **13**, 61.)

DIXON. Water supply.—(Bull. **11**, 58; **13**, 61.)

DOWNERS GROVE. Water supply.—(Bull. **13**, 61.)
Sewerage and sewage disposal.—(Bull. **13**, 62.)

DUQUOIN. Water supply.—(Bull. **9**, 19; **11**, 58; **13**, 62.)
Sewage disposal.—(Bull. **12**, 56; **13**, 63.)

DWIGHT. Water supply.—(Bull. **12**, 57.)
Sewerage and sewage treatment.—(Bull. **12**, 57.)

EARLVILLE. Water supply.—(Bull. **9**, 20.)

EAST DUBUQUE. Water supply.—(Bull. **11**, 60.)

EAST DUNDEE. Water supply.—(Bull. **9**, 20.)

EAST MOLINE (2,665). Water supply.—Visited October 12. East Moline is in Rock Island County about throe miles from the city of Moline. It is a rapidly growing manufacturing city. Some citizens estimate the present population as high as 10,000.

The waterworks is owned by the city. Water is obtained from two wells equipped with air lifts located about 1,000 feet apart near the center of the city. The depth of one well is 1,300 feet and that of the other one is over 2,000 feet. Water flows from the wells into a concrete reservoir. It is pumped from this reservoir into the distribution system by two 5-inch electrically driven two-stage centrifugal pumps. There are two elevated steel tanks connected to the distribution system. Nearly all residents use water from the public supply.

The water is of good sanitary quality. It has a mineral content of 1,15 0 and a total hardness of 350 parts per million. It contains no iron.

EAST PEORIA (1,493). Water supply.—(Bull. **11**, 61; **12**, 58.) Visited December ,13. East Peoria is a manufacturing community in the northern part of Tazewell County near Illinois River and across the river from Peoria. It has no public sewers.

Waterworks were installed in 1916. Water is obtained from four wells in the southeastern part of the village. Each well is 6 inches in diameter and about 25 feet deep. They penetrate about three feet of loam and about 23 feet of sand and gravel. The static water level is at a depth of 6 or 8 feet. A neat brick pumping station and a 100,000-gallon concrete surface reservoir are located near the wells. In the station are two 8¼-inch by 10-inch electrically driven triplex pumps. The pumps can draw water directly from the wells or from the reservoir and can discharge into the reservoir or into the distribution system. The distribution system includes 6.7 miles of mains from 4 inches to 12 inches in diameter, 72 hydrants, 28 valves, and 45 service connections. A steel standpipe located on high ground is connected to the distribution system. A gage in the pumping station registers 207 feet pressure when the standpipe is full. The total cost of the waterworks was about $66,000.

The water is of good sanitary quality but certain insanitary conditions on land close to the village wells should be improved to prevent the possibility of contamination. The water has a mineral content of 369, a total hardness of 306, and a content of iron of 0.25 parts per million.

EAST ST. LOUIS. Water supply.—(Bull. **11**, 61; **13**, 63.)
Pollution of Cahokia Creek.—(Bull. **13**, 63.)

EAST WENONA (367). Water supply.—(Bull. **13**, 65.) Visited December 14. East Wenona is in La Salle County east of and adjoining Wenona. The public water supply is obtained from Wenona. The distribution system includes about 3500 feet of 4-inch pipe and 37 service connections.

EDWARDSVILLE. Water supply.—(Bull. **12**, 58.)
Sewage disposal.—(Bull. **12**, 59.)

EFFINGHAM. Water supply.—(Bull. **10**, 108; **11**, 63; **13**, 65.)
Disposal of wastes from catsup factory.—(Bull. **9**, 20; **10**, 108.)

ELDORADO. Proposed water supply and sewerage.—(Bull. **9**, 20.)

ELGIN (25,976). Water supply.—(Bull. **9**, 20.) Visited August 27 to 29, August 31, to September 2, and September 6 in connection with an investigation of a typhoid-fever epidemic at Elgin. The typhoid-fever resulted from the pollution of a drinking water supply at the Elgin National Watch Company factory by water from Fox River. Investigation did not show that the city water was the cause of any typhoid fever.

Waterworks were installed in 1887 and 1888 with Fox River as the source of supply. Wells have been drilled and river water has not been used since 1911 although pressure filters for purifying the river water are still maintained. One well 2,000 feet deep and three wells 1,300 feet deep are pumped by either of two centrifugal pumps placed in the bottom of a 120-foot shaft which is connected to the wells by tunnels. These pumps discharge into collecting reservoirs.

In 1914 a well was dug into limestone to a total depth of 38 feet. The upper 13 feet is 8 feet square and the remainder is 5 feet 10 inches in diameter. The walls of the well are lined with concrete and the well is surmounted by a brick building. Water is derived from crevices in the stone at the bottom of the well. The static water level is about 28 feet below the ground surface. A 1,000,000-gallon centrifugal pump direct connected by a vertical shaft to an electric motor is placed about 2 feet above the bottom of the well. The yield of the well is less than 1,000,000 gallons a day and the pump discharge is reduced to 600,000 gallons by partly closing a valve.

Two 1,500,000-gallon pumps and one 6,000,000-gallon pump are available to force water into the distribution system. At the end of 1913 there were 60.8 miles of water pipe from 4 inches to 24 inches in diameter. The pressure in the distribution system ranges from 50 to 100 pounds. At the end of 1914 there were 5,514 service connections, of which 5,028 were metered. The installation of meters had reduced the consumption to an average of 1,406,000 gallons a day in 1914. In 1915 a 500,000-gallon elevated steel tank was erected. The water department on December 31, 1913, valued the waterworks at $616,688. In 1914 the income was $61, 302.17, operation and repairs cost $47,011.43, and payments on bonds and interest were $10,420.

The water is of good sanitary quality. The water from the 1300-foot wells has a mineral content of 375, a hardness of 288, and a content of iron of one part per million. The water from the dug well has a mineral content of 388, a hardness of 306, and a content of iron of 0.8 parts per million.

ELGIN. Factory water supplies.—Inspections were made of water supplies at several factories on August 27 to 29, August 31 to September 2, and September 6 in connection with an investigation of a typhoid-fever epidemic at Elgin. An epidemic resulted from pollution of a drinking water supply by Fox Eiver water at the factory of the Elgin National Watch Co. as described on pages 35 to 39.

The water supply of the Y. M. C. A. and the factories of the Elgin Manufacturing Co., Illinois Watch Case Co., Cutter and Crossette Co., Selz-Schwab Co., D. C. Cook Publishing Co., and Western Thread Co., were investigated. The sources of supply and possibilities of contaminating drinking water supplies by impure water supposed to be used only in case of fire or for other purposes were investigated. No evidence of contamination was found. Minor improvements were recommended at some plants. The Western Thread Co. filters its supply. Before filtration the water passes through tanks in which it is subject to possible pollution by surface drainage. Better protection of the water in these tanks was advised.

ELGIN. Elgin National Watch Co. water supply and its relation to a typhoid-fever epidemic.—Visited August 27-29, August 31 to September 2 and September 6, at the request of the State Board of Health in connection with an investigation by them of an epidemic of typhoid fever resulting from the pollution of the water supply at the factory.

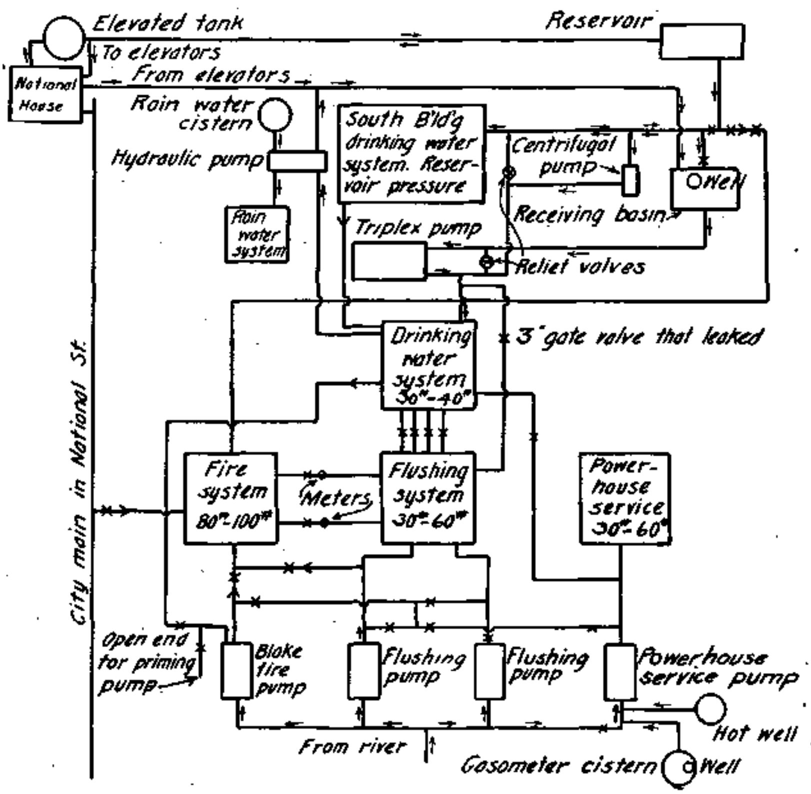
Cases of typhoid fever began to develop in Elgin in June. In August the city physician made an investigation and concluded that the source of infection was at the factory of the Elgin National Watch Co. He found that water taken from drinking fountains in the factory was contaminated and that the city supply at the time was of good sanitary quality. The company officials were notified and the State Board of Health took charge of the further control and investigation of the epidemic.

The Elgin National Watch Co. factory is located in the southern part of Elgin on the eastern bank of Fox River. About 3000 persons are employed. A lodging and rooming house for employees located close by, known as the National House, is owned and operated by the Company. There are 6 water supplies in the factory as follows: Drinking water, rain water, fire protection, power house, hot water and flushing water. "Water taken from the Tiver for fire protection, power house service and flushing is badly polluted by sewage from the city and the factory.

Drinking water is obtained partly from a well 2000 feet deep on the premises and partly from the city supply. Water is pumped from the well by air lift into a receiving basin. City water is supplied to the National House and connections are made to an elevated tank and to a reservoir on a hill near the factory. Waste water from hydraulic elevators in the National House flows into the receiving basin at the well. The pipe line from the reservoir on the hill is connected to the drinking water distribution system in one factory building, known as the South Building, and through a float controlled valve to the receiving basin at the well. The pipe line is also connected to a centrifugal pump formerly used to boost the pressure in the drinking water distribution system, but which is not now in use. Water is pumped from the receiving basin into the drinking water distribution system of all factory buildings except the south building. In some buildings the water is cooled by passing through ice coils at each drinking fountain. The supply at the north building and at the west building passes through a float controlled valve into a cooling tank equipped with ammonia coils and is pumped from this tank to fountains in the two buildings. During warm weather drinking water used at the National House is cooled by adding artificial ice directly to the water in a large lead-lined tank located in the attic.

The wells and tanks in the drinking water system, as far as could be learned, were protected from contamination. The reservoir on the hill is covered with earth and surrounded by well-kept lawns. It is provided with a ventilator with small windows covered with ¼ inch mesh screen. An overflow pipe from the receiving basin was equipped with an inverted siphon trap placed inside the basin after the typhoid fever outbreak. The lead-lined tank used as a cooling tank for the National House drinking water supply is cleaned and scrubbed once or twice a week. It would be better to allow a deposit to remain on the lead in order to lessen the possibility of lead, which is injurious to health, being dissolved by the water.

Rain water used to wash dial copper is pumped from two cisterns into a distribution system by a pump operated by water from the drinking water system. The water used by the pump is returned to the receiving basin through



Diagrammatic sketch showing interrelation of water supply systems at the Factory of the Elgin National Watch Co.

Where the direction of flow is not indicated, flow may be in either direction dependent upon the pressures and the position of valves. Only the principal valves are indicated. Under ordinary conditions the valves between the different systems were kept closed.

✕ = hand operated valve. ⇸ check valve.

a connection to the line from the National House elevators to the basin. There are no cross connections between this system and any of the other systems.

A fire protection distribution system supplies water to sprinkler heads in the factory buildings and to several fire hydrants. Pressure is maintained with city water except at times of fire when water may be drawn from an intake well connected by conduit to Fox river, and discharged into the system. Water may also be supplied to the fire protection system by pumps which are ordinarily used to supply river water for the flushing system or by a pump used to supply water to the power house service system.

The power house supply may be taken from the intake well connected by conduit with Fox River, from a "hot well" or from a well 1000 feet deep located in the southwest part of the factory property. Water is pumped from the well by air lift into a reservoir, formerly part of a gasometer, known as the gasometer cistern. It has 24-inch brick walls laid in cement and a cemented bed rock bottom. Water is ordinarily pumped into the power house service distribution system by a Prescott duplex pump. Water may be supplied to this system by the pumps ordinarily used to furnish river water to the flushing system.

A hot water distribution system is supplied with river water or with well water from the gasometer cistern.

Flushing water is used for flushing toilets and for sprinkling lawns about the factory during the summer. The supply is drawn from the river through the intake well and is interconnected with the power house supply.

A diagrammatic sketch showing the interrelation of the water supply systems before changes were made following the epidemic is shown on page 37.

The suction and discharge pipes of pumps supplying river water to the fire, flushing and power house service systems are connected. The connection from the discharge of the flushing service pump to the fire protection system is an 8-inch pipe with a check valve opening toward the fire system and a gate valve.

There is an 8-ineh connection between a city main and the fire protection system. On this connection are a gate valve and a cheek valve opening toward the fire protection system.

There was a 1-inch and a 1½-inch connection between the fire and flushing systems. On each connection was a hand operated valve and a meter to measure the flow of city water from the fire system to the flushing system. On Aug. 28 the city pressure in the fire protection system was 84 pounds and the pressure in the flushing system on the other side of the valve was 65 pounds.

There was a connection from the fire protection system to the drinking water system between the reservoir and the receiving well.

A 1½-inch pipe connected the fire pump with the drinking water supply. This was used for priming the pump.

The power house service pump discharge was connected to the drinking water distribution system by a 4-ineh pipe controlled by a gate valve.

A 3-inch pipe controlled by a valve connected the discharge of the triplex drinking water supply pump and the flushing system.

The pressure on the drinking water supplies varies from about 30 pounds to 40 pounds. The pressure maintained in the flushing system varies from 30 pounds during the winter to 60 pounds in the summer when water is used for sprinkling purposes. Thus the pressure in the flushing system is at times 15 to 20 pounds in excess of that in the drinking water system. During June the maximum temperature was 73 degrees and the rain fall was 6.64 inches so sprinkling was probably unnecessary. During July the mean maximum temperature was 92 degrees, the mean minimum temperature 65 degrees and the total rain fall only .33 inches. Sprinkling became necessary early in July and the pressure in the flushing system was increased.

When notified of the contamination of the water supply the Watch Co. made an examination of the drinking water supply and removed the cross connections between that supply and the flushing supply. The 3-inch cross connection in the triplex pump room was disconnected on the drinking water supply side of the valve and river water was found to be leaking through the valve. The hand wheels on this and several other valves had been removed in order to avoid danger of the valves being accidentally opened. This leakage contaminated the drinking water supply of all factory buildings except the south building which is supplied directly from the reservoir. Only one case of typhoid fever developed among employees in the south building. Whether or not this patient drank water elsewhere in the factory was not ascertained.

In order to prevent the contamination of the city supply from the factory fire supply, should the check valve in the connecting pipe fail to seat, the company plans to remove the connection, install an elevated tank of about 100,000 gallons capacity to be connected to the fire protection system and, in case of emergency, obtain water from the city supply by making hose connections between hydrants on the two supplies.

ELGIN. Proposed sewage treatment.—(Bull. **9**, 147; **12**, 60.)

ELGIN. State Hospital. Water supply and typhoid fever.—(Bull. **10**, 109.)

ELMHUEST. Proposed improved water supply.—(Bull. **11**, 64; **12**, 61.)
Sewerage.—(Bull. **11**, 64.)
Sewage pollution of Salt Creek.—(Bull. **12**, 61.)

ELMWOOD. Water supply.—(Bull. **12**, 62.)

EL PASO. Water supply.—(Bull. **10**, 109.)
Disposal of corn-canning wastes.—(Bull. **10**, 110; **13**, 66.)

EUREKA. Water supply.—(Bull. **12**, 62.)
Disposal of cannery wastes.—(Bull. **12**, 235.)
Proposed sewerage.—(Bull. **13**, 67.)

EVANSTON. Water supply.—(Bull. **9**, 21; **10**, 110; **13**, 67.)

FAIRBURY. Water supply.—(Bull. **9**, 22; **12**, 63.)

FAIRFIELD. Water supply.—(Bull. **9**, 22; **10**, 110; **12**, 64.)
Proposed sewerage and sewage treatment.—(Bull. **12**, 65.)

FARMER CITY. Water supply.—(Bull. **10**, 111.)
Sewerage.—(Bull. **10**, 111.)

FARMINGTON. Water supply.—(Bull. **12**, 65; **13**, 67.)
Sewerage and sewage disposal.—(Bull. **12**, 66; **13**, 68.)

FLORA. Water supply.—(Bull. **9**, 22; **12**, 67.)
Sewerage.—(Bull. **12**, 68.)

FORREST (967). Water supply.—Visited November 14. Forrest is in the southeastern part of Livingston County on the drainage area of Vermilion River. There is no sewer system in the village.

Waterworks were installed about 1895. Water was pumped from a well near the center of the village into the distribution system and an elevated tank. About 15 years ago two coal shafts which had been dug in the southwest part of the village to a depth of 80 feet and abandoned, were leased by the city and have since been used as a source of supply. Water stands about 8 feet below the ground surface when not pumping and is lowered 9 feet by long continued pumping. Water is pumped into the distribution system by an 8-inch by 9¼-inch triplex pump driven by an 18-horsepower gasoline engine. The distribution system includes about 2,240 feet of 6-inch and 5,000 feet of 4-inch pipe, 19 fire hydrants, and 50 service connections. The consumption is estimated as about 4,700 gallons per day. An elevated wooden tank, 20 feet in diameter and 22 feet high, erected about 1895 is in use but 'must soon be replaced. An analysis of the water indicated that it was safe for drinking purposes at the time of the visit. The wells or shafts do not have water-tight covers and the supply is not adequately protected from contamination. The water has a mineral content of 637, a total hardness of 493, and a content of iron of 2 parts per million.

FOREST PARK. Water supply.—(Bull. **10**, 112.)

FORRESTON. Water supply.—(Bull. **11**, 65.)

FORT SHERIDAN. Water supply.—(Bull. **9**, 23; **10**, 112; **13**, 68.)

FOX RIVER WATER SHED.—(Bull. **9**, 147; **11**, 66.)

FREEBURG. Water supply.—(Bull. **11**, 66.)

FREEPORT. Water supply.—(Bull. **10**, 113; **13**, 68.)

FULTON. Water supply.—(Bull. **11**, 67.)
Sewerage.—(Bull. **11**, 68.)

GALENA. Water supply.—(Bull. **11**. 69; **12**, 68.)
Sewage disposal.—(Bull. **12**, 68.)

GALESBURG. Water supply.—(Bull. **9**, 23; **10**, 114; **12**, 69; **13**, 71.)
Sewage disposal.—(Bull. **9**, 23; **10**, 114; **12**, 70.)
Pollution of Cedar Creek.—(Bull. **9**, 23; **10**, 114; **12**, 70; 196-224; **13**, 72.)

GALVA. Water supply and sewage.—(Bull. **10**, 115.)

GENESEO. Water supply.—(Bull. **10**, 116.)
Pollution of Geneseo Creek by city sewage.—(Bull. **10**, 117; **11**, 70; **12**, 70.)

GENEVA. Water supply.—(Bull. **9**, 23.)
Sewage treatment.—(Bull. **12**, 70.)

GENEVA. Illinois State Training School for Girls. Plans for sewage treatment.—(Bull. **12**, 71.)

GENOA. Water supply.—(Bull. **11**, 70.)
Sewage disposal.—(Bull. **12**, 71; **13**, 72.)

GEORGETOWN. Proposed water supply.—(Bull. **9**, 24; **10**, 117.)
Proposed sewerage and sewage treatment.—(Bull. **12**, 72.)

GIBSON CITY. Water supply.—(Bull. **10**, 118.)
Disposal of cannery wastes.—(Bull. **12**, 73.)
Typhoid fever.—(Bull. **10**, 118; **13**, 73.)

GILLESPIE. Sewerage.—(Bull. **13**, 73.)

GILMAN. Water supply.—(Bull. **11**, 71.)

GIRARD. Proposed water supply.—(Bull. **11**, 71.)

GLENCOE. Water supply and sewerage.—(Bull. **9**, 24.)

GLEN ELLYN. Water supply.—(Bull. **12**, 73.)
Sewage disposal.—(Bull. **12**, 74.)

GLENVIEW (652). Water supply.—Visited November 29. Glenview is in the northern part of Cook County on a branch of Chicago River. Waterworks were being installed at the time of the visit. The source of supply is a well 12 inches in diameter at the top, 6 inches in diameter at the bottom and 1251 feet deep, about 3 feet being in Potsdam sandstone. When not pumping the static water level is 53 feet below the surface. After 7 hours and 50 minutes pumping at rates of from 132 to 152 gallons per minute this water level was lowered to a depth of 66.8 feet.

An electrically driven deep-well pump has been installed, to force water into the distribution system. A distribution system including 4.4 miles of mains from 4 inches to 10 inches in diameter, 40 hydrants, and 20 valves has been completed. An elevated steel tank to be connected to the distribution system was being erected in November.

GRAFTON. Pollution of Illinois River.—(Bull. **11**, 72.)

GRAND RIDGE. Water supply.—(Bull. **11**, 72; **13**, 74.)

GRANITE CITY. Water supply.—(Bull. **11**, 72; **13**, 74.)
Proposed improved sewerage.—(Bull. **13**, 75.)

GRANVILLE. Water supply.—(Bull. **13**, 75.)

GRAYSLAKE. Sewage disposal.—(Bull. **12**, 75; **13**, 76.)

GRAYVILLE. Water supply.—(Bull. **10**, 119.)

GREAT LAKES, Naval Training Station. Water supply.—(Bull. **9**, 28; **11**, 34; **13**, 76.)

GREENUP. Water supply.—(Bull. **10**, 119; **11**, 74; **13**, 76.)

GREENVIEW. Water supply.—(Bull. **11**, 75.)

GREENVILLE. Sewerage and sewage disposal.—(Bull. **11**, 75; **12**, 76; **13**, 77.)

HAMILTON. Water supply.—(Bull. **10**, 120; **11**, 76; **13**, 77.)

HARMON (162). Water supply.—(Bull. **10**, 121.) Visited December 27. Harmon is in the west central part of Lee County.

The village drilled a well in 1909, purchased a pump and built a pumping station in 1910 and installed a distribution system and erected an elevated tank in 1912. The well is 5 inches in diameter and 532 feet deep. Water is pumped from the well into the distribution system by a 30-gallon per minute deep-well pump driven by a 14-horsepower gasoline engine. When not pumping the static water level is about 7 feet below the surface and during pumping it is lowered to a depth of 60 to 90 feet. The distribution system includes about 4,000 feet of 4-inch, 6-inch and 8-inch mains, 11 hydrants, and 6 service connections. A 30,000-gallon elevated steel tank on an 80-foot steel tower is connected to the distribution system, to which are connected only 2 residences, 3 business houses, and the railroad depot.

The water is of good sanitary quality. It has a mineral content of 348, a total hardness of 299, and a content of iron of 0.6 parts per million.

HARRISBURG. Water supply.—(Bull. **9**, 24; **10**, 121; **11**, 76; **12**, 76; **13**, 77.)
Pollution of public water supply by improper sewage disposal.—(Bull. **11**, 77; **13**, 79.)

HARVARD. Water supply.—(Bull. **12**, 78.)
Sewage disposal.—(Bull. **10**, 122; **12**, 79.)

HARVEY. Water supply.—(Bull. **13**, 81.)
Investigation of Nuisance.—(Bull. **10**, 123.)

HAVANA. Water supply.—(Bull. **12**, 79.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **11**, 77.)

HENNEPIN. Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 24.)

HENRY. Water supply.—(Bull. **12**, 80.)
Pollution of Illinois River.—(Bull. **11**, 77.)

HERRIN. Water supply.—(Bull. **10**, 125; **13**, 82.)
' Proposed Sewerage.—(Bull. **10**, 125.)

HEYWOETH (681). Proposed water supply.—Visited December 12. Heyworth is in the southwestern part of McLean County on the drainage area of Sangamon Eiver.

The installation of a public water supply has been proposed but little progress is being made at present. Shallow dug wells arc generally used. There are a few drilled wells. A well has been drilled in the village to a depth of 238 feet but it is reported that with the exception of a small flow in sand and gravel that a depth of 110 to 115 feet no water was obtained. A sample of water collected from a drilled well 80 feet deep contained iron, calcium, and magnesium in quantities undesirable in a public supply. There are large deposits of gravel near a creek a short distance north of the village but the quantity or quality of water that could be secured from wells in this gravel is not known. The advisability of installing a public supply was discussed with village officials.

HIGH LAKE. Proposed water supply.—(Bull. **9**, 24.)

HIGHLAND. Proposed water supply.—(Bull. **10**, 126; **13**, 83.)
Proposed sewerage.—(Bull. **13**, 83.)

HIGHLAND PARK. Water supply and sewerage.—(Bull. **9**, 24; **10**, 126.)
Sewage treatment.—(Bull. **9**, 24; **13**, 83.)

HILLSBOEO. Water supply.—(Bull. **10**, 127; **12**, 81; **13**, 84.)
Sewage pollution of Middle Fork of Shoal Creek.—(Bull. **12**, 83.)

HINCKLEY. Water supply.—(Bull. **11**, 78.)

HINSDALE. Water supply.—(Bull. **11**, 78; **13**, 84.)

HOLLYWOOD. Water supply.—(Bull. **13**, 86.)

HOMER. Pollution of private wells.—(Bull. **12**, 84; **13**, 86.)

HOMEWOOD. Water supply.—(Bull. **12**, 84.)

HOOPESTON. Water supply.—(Bull. **10**, 128.)

HOOPESTON (4,698). Flooding of cellars by sanitary sewage.—Hoopeston was visited January 10 and 11, in response to a request from the State Board of Health, for the purpose of investigating an alleged nuisance caused by flooding of cellars from sanitary sewers. A general examination of the system of sanitary sewers and of a storm drain laid through the eastern part of the city was made. Cellars of about fifty houses located on comparatively low ground near the storm drain in the southeastern part of the city have been flooded several times, since sanitary sewers were installed. The storm drain is not of adequate capacity. Cellars are connected to both the storm drain and the sanitary sewers and when the storm drain is overtaxed water backs up into cellars and flows into the sanitary sewers. These become overloaded and sewage backs up into other cellars including those which do not have storm-water connections. The flooding of the cellars is a nuisance and creates insanitary and unhealthful conditions. The city should make a thorough investigation and correct faulty conditions.

HOOPESTON. Sewage disposal.—Hoopeston was visited July 27, September 15 and 16, and December 14 to make examinations of the condition of a small drainage ditch receiving city sewage and wastes from corn-products factories.

The sewage from the city of Hoopeston is discharged through a septic tank into a small drainage ditch which has a small flow during the greater part of the year. In the fall of the year the quantity of sewage is materially increased by the addition of from 20,000 to 40,000 gallons per day of wastes from corn-products factories.

On July 27, the canning factories were not in operation. Previous to the inspection there had been no rain for 4 or 5 weeks. The flow in the stream was very small and accordingly the examination showed the conditions that would prevail when only domestic sewage is being discharged into the stream. At the sewer outlet the sewage amounted to about one-third of the total flow in the stream.

Above the outlet the water in the stream was representative of surface drainage. The tank effluent was odorless and practically clear but in a small back-water near the sewer outlet there was some putrefaction, the water was colored, and had a disagreeable odor. Within a distance of ¾ of a mile down stream, where the flow was practically continuous, there were no unsightly conditions and no disagreeable odors. At the junction of the stream and the North Fork of Vermilion River, two miles down stream, the water was clear and had the appearance of unpolluted surface drainage.

During the examination of the stream samples were collected for chemical, bacteriological, and dissolved oxygen determinations. The analyses showed that the raw sewage was very weak, the septic tank effluent was somewhat stronger and that the tank was working under anaerobic conditions. The sample from above the tank outlet gave results typical of surface drainage, no pollution being indicated. Below the outlet the effect of the sewage was shown by the increase in chlorine, ammonia and albuminoid nitrogen, and a decrease in dissolved oxygen. Progressive samples down stream showed a gradual clearing up and at a point ¾ of a mile below the tank outlet there was sufficient dissolved oxygen present in the water for complete purification.

A second investigation was made on September 15 and 16 especially to determine the conditions in the stream while the canning factories were discharging wastes into the sewers. The greater part of the factory wastes come from the almost continuous washing and flushing of the floors and the occasional washing of the machines. There had been practically no rain for several weeks previous to the investigation and the flow in the stream above the tank was almost nil. The water was fairly clear but had the appearance of stagnant surface drainage there being algae and other growths, in pools and along the banks. At a point a few feet below the sewer outlet the stream bed was almost completely covered with growths of typical sewage organisms and the banks were lined with sludge beds. These conditions prevailed the entire length of the stream and extensive sludge banks had formed at the junction of the stream with North Fork of Vermilion River. The flow in the stream was slow and sluggish, the water was dark colored and when stirred it gave off foul odors typical of gas odors from sludge banks formed from sewage deposits. Conditions farther down stream were similar. In general the conditions in the stream were worse than at the time of the previous investigation, due at least in part to the difference in dilution of the sewage received.

Dissolved oxygen and putrescibility tests were made in the field and sanitary analyses of samples collected were made in the laboratory. The results of the analyses show that conditions in the stream were very bad and bear out the physical examinations.

The third visit was made at a time of high-water and when canning factory wastes were entering the stream. Just below the outfall of the septic tank there was a slight odor and the water was rather black but not in extremely bad condition. Three-fourths of a mile down stream the ditch was apparently in good condition. The physical, chemical and bacteriological examinations showed that the stream was satisfactorily diluting the sewage so that foul conditions did not result. This was probably due to the existing conditions of stream flow and low temperature.

The first examinations of the stream did not reveal evidences of excessive pollution, but it is quite probable that as the quantity of sewage from Hoopeston increases foul conditions will result. The second visit brought out the fact that with an increase in the quantity of sewage discharged into the stream, foul conditions do result. The third visit revealed the fact that with high-water conditions a general clearing up of the sludge beds and bad odors can be expected.

In order to prevent the formation of sludge beds and foul odors at all times it would be necessary to treat the sewage more thoroughly before discharging it into the stream.

ILLINOIS RIVER. Examination of Illinois River between the cities of Morris and Peoria.—An-examination of Illinois River between the cities of Morris and Peoria was made October 28 to 30 at the request and under the direction of the State Laboratory of Natural History to investigate alleged nuisance caused by Chicago sewage. The river is grossly polluted by Chicago sewage. On account of extremely hot and dry weather the river was in worse condition than had been observed in past years. At Morris, Ottawa and Peru the most obvious evidences of pollution were noted. At Henry the current of the river was so slacked by the dam as to cause sedimentation of most of the suspended matter. Much better conditions were observed at Peoria and although there was a swift current, there was little or no suspended matter, the water had a distinct green color and the only odors noticeable were those one might expect of a normal clear stream.

IPAVA. Water supply.—(Bull. **12**, 85.)

JACKSONVILLE. Water supply.—(Bull. **10**, 129; **12**, 85.)

Sanitary inspection of Chautauqua ground.—(Bull. **12**, 87.)

JACKSONVILLE. Illinois School for the deaf.—(Bull. **13**, 86.)

JERSEYVILLE. Water supply.—(Bull. **12**, 88.)

JOHNSTON CITY (3,248). Proposed improved water supply.—(Bull. **11**, 79.) Visited April 25 to examine a site for wells proposed as the source of an improved water supply.

The public water supply is now obtained partly from two small storage reservoirs on Lake Creek and partly from two tubular wells about 300 feet deep. The creek water is used when available as it is cheaper to pump and less highly mineralized than the well water. This supply is inadequate. The Central Illinois Public Service Co., owners of the plant, planned to develop a supply from a well entering limestone overlying a mine of the Williamson County Coal Co. If the yield was insufficient, it was proposed to continue the drilling into the mine workings. Rock is entered in this locality at a depth of 20 feet and coal overlain by shale is entered at about 180 feet. Cracks in the roof of the mine admit about 500,000 gallons of water a day. Thia would be piped to the well, if the well is continued into the mine workings. A 10-inch well, drilled to a depth of 185 feet on April 25, yielded less than 4.000 gallons a day. Since then the well has been drilled to a depth of 215 feet,

Water from the well 215 feet deep had a mineral content of 3542, a hardness of 662, and a content of iron of 56 parts per million. Samples of water from four other sources were analyzed. Water from the crevice in the mine roof was as hard as the water from the well but contained less total mineral matter and only one part per million of iron. Water from the Oak Ridge mine had a mineral content of 1243 and a hardness of 812 parts per million. It contained no iron.

Samples of water from the northeast drill hole at the mine of the Southern Illinois Coal and Coke Co. and from the bottom of the shaft of the Holland mine were of better quality. They had mineral contents of 1037 and 725 and hardness of 140 and 298 parts per million, respectively.

JOLIET. Water supply.—(Bull. **11**, 79.)

Illinois State Penitentiary, water supply.—(Bull. **11**, 81.)

KANKAKEE. Water supply.—(Bull. **11**, 83; **13**, 88.)

KANSAS. Proposed water supply.—(Bull. **13**, 88.)

KEITHSBURG. Water supply.—(Bull. **12**, 89.)

KEMPTON (269). Water supply.—Visited November 15. Kempton is in the northern part of Ford County. There are a number of tile drains but no sewers in the village.

Waterworks were installed in 1894. At that time only one block of mains were laid. The system has since been improved. The present source of supply is a well 8 inches in diameter and 404 feet deep terminating in rock. The static water level is probably about 80 feet below the surface when not pumping and with long-continued pumping it is probably drawn down to the pump cylinder at a depth of about 318 feet. Water is pumped from the well into two steel pressure tanks 8 feet in diameter and 20 feet long by a deep-well pump of small capacity.

In the rear of the pumping station is a concrete reservoir with a concrete' cover. It may be filled from the wells or at time of rains by water from near-by roofs. A 7-inch by 10-inch horizontal duplex pressure pump may be used to draw water from this reservoir and discharge it into the distribution system at times of fire.

A 15-horsepower gasoline engine furnishes power to operate the pump's a small air compressor, and a dynamo which furnishes the current for street lighting. A smaller engine formerly used is held in reserve.

The distribution system includes about 350 feet of 6-ineh and 3,300 feet of 4-inch wrought-iron pipe, 370 feet of cast-iron pipe, 11 hydrants, 5 valves, and about 90 service connections. All but 10 houses in the village use water from the public supply. All services are metered.

The water is of good sanitary quality. It has a mineral content of 820 parts per million of which 670 parts are sodium carbonate, a hardness of 20 parts per million and a content of iron of 0.3 parts per million;

KENILWORTH. Water supply.—(Bull. **9**, 24; **13**, 88.)

KEWANEE. - Water supply.—(Bull. **10**, 130.)

KIRKWOOD. Water supply.—(Bull. **10**, 131.)

KNOXVILLE. Water supply.—(Bull. **9**, 25; **10**, 131; **12**, 90; **13**, 88.)
Sewage disposal.—(Bull. **12**, 90.)

LACON. Water supply.—(Bull. **12**, 91.)

LADD. Water supply.—(Bull. **11**, 84; **12**, 91; **13**, 88.)

LAGRANGE. Water supply.—(Bull. **13**, 89.)
Sewage-treatment plant.—(Bull. **10**, 134.)

LAGRANGE PARK. Water supply.—(Bull. **13**, 90.)

LA HARPE. Water supply.—(Bull. **12**, 92.)

LAKE BLUFF. Water supply and sewerage.—(Bull. **9**, 25; **10**, 135.)

LAKE FOREST. Water supply.—(Bull. **9**, 25; **12**, 93; **13**, 90.)
Sewage disposal.—(Bull. **9**, 25; **11**, 85.)

LAKE ZURICH. Water supply.—(Bull. **13**, 90.)

LAMOILLE (555). Proposed water supply.—Visited October 19-20. LaMoille is in the northwestern part of Bureau County on the drainage area of Big Bureau Creek. Work on the installation of a public water supply began shortly after a fire on March 19, 1915, which destroyed part of the business district of the village. A well 8 inches in diameter at the top and 6 inches at the bottom has been drilled to a depth of 268 feet. In the bottom of the well is a screen 4½ inches in diameter and 14 feet long. The static level is 137 feet below the surface. Pumping 1½ hours at a rate of about 32 gallons per minute lowered the level 3½ feet. Water is to be pumped directly into a distribution system by an electrically driven deep-well pump. An elevated tank is to be connected to the distribution system.

The water from the well is of good sanitary quality. It has a mineral content of 526, a hardness of 349, and a content of iron of 6 parts per million.

LANARK. Water supply.—(Bull. **11**, 85.)

LA ROSE. Proposed water supply.—(Bull. **13**, 91.)

LA SALLE. Water supply.—(Bull. **11**, 86.)
Investigation of the pollution of two deep wells.—(Bull. **9**, 25.)

LAWRENCEVILLE. Pollution of Embarrass River and Indian Creek by oil.—Lawrenceville, Bridgeport and the surrounding country were visited on April 28, at the request of the Rivers and Lakes Commission to investigate the alleged pollution of Embarrass River and Indian Creek by crude oil from oil wells and by wastes discharged from the plants of the Indian Refining Co. and the Central Refining Co.

Lawrenceville and Bridgeport are located in the central part of Lawrence County in the heart of extensive oil fields. The Indian Refining Co., the Central Refining Co., and the Ohio Refining Co. own many wells in the county. The first two companies have refineries located at Lawrenceville and the Ohio Oil Co. pumps its crude oil to eastern refineries. As the number of oil wells and the amount of oil produced has increased, the pollution of the near-by watercourses by oily wastes has also increased. The prosperity of the community is largely dependent on the oil industry. Although many people undoubtedly realize that the streams are at times grossly polluted very few open complaints have been made, probably for fear of arousing criticism of people receiving financial gains from the production of oil.

The drainage area of Embarrass River comprises 2410 square miles in the southeastern part of the state. The river rises in Champaign County and discharges into Wabash River about eight miles southeast of Lawrenceville. The annual rainfall on the drainage area is about 40 inches. During periods of extreme drought the stream flow is small. In wet seasons large areas of bottom lands throughout the entire length of the river are inundated. Indian Creek rises to the west of Bridgeport and enters Embarrass River just southeast of Lawrenceville. Many oil wells, especially those of the Ohio Oil Co., are located on its drainage area. At times of dry weather it would have no natural flow but, due to the wastes discharged into it, it probably never goes entirely dry.

Inspection was made of oil territory to the south of Lawrenceville along Indian Creek and to the west of Bridgeport along the same creek. Some oil wells are located on high ground and others are on low ground reached by flood waters. Around some oil wells on cultivated land just west of the Baltimore and Ohio depot at Lawreneeville the ground is entirely free from any evidence of oil pollution. Around other wells the ground is covered with oil. This oil comes from leakage from the tops of the well casings during pumping and possibly also from occasional openings of taps in the tops of the wells allowing the crude oil to be discharged directly upon the ground. The Ohio Oil Co. appears to be the worst offender. At the time of the visit Indian Creek as it passed through the Bridgeport public park at the southwestern edge of that city was entirely covered with a layer of oil and the banks of the stream were coated with deposits of crude oil. Large quantities of crude oil were on the ground surrounding the wells, sufficient in amount in some instances to cause a flow into the stream. During and following rains much crude oil is washed into the streams forming an oily film over the water.

At the time of the visit there was no evidence of oil pollution on the waters of Embarrass River from the oil fields to the north of Lawreneeville. Persons interviewed, however, state that at times of rain large sheets of oil are brought down by the river from the northern territory.

The two oil refineries are located at the southeastern edge of Lawreneeville. The plant of the Indian Refining Co. is considerably larger than the plant of the Central Refining Co. In these plants crude oil as received from the wells is stored in large storage tanks. When it is distilled, the distillates pass through coils of pipe surrounded by water in condenser pans. The condensed distillates are stored in cylindrical steel tanks called "run-down" tanks. The benzine, gasoline, and lubricating oil distillates then go to what are called agitators where they are washed with sulphuric acid and caustic soda solutions. They are then passed through a filter house. The greatest volume of waste consists of the water used for condensing but this water does not come in direct contact with the oil and carries little pollution. The sludge from the agitators is shipped away in tank cars. Wherever the oils or distillates are retained in tanks, water and impurities settle to the bottom and by means of a valve-controlled outlet in the bottom of the tanks, they are drawn off into underground drains running through the plant. The polluted wastes consist mostly of liquor drawn from the bottom of the different storage and run-down tanks. The drains are supposed to collect all liquid wastes including surface drainage. On the outlying edges of the grounds of the plants, however, there are limited areas which become polluted with oil wastes, and which drain off or wash off in times of rain directly into watercourses.

At each plant the wastes collected in the drains are passed through a baffled settling tank of a capacity equal to about 4 or 5 hours' flow of the wastes treated. Oil rises to the surface, and water passes under the baffles to outlet pipes. Oil is pumped from the surface of the tanks and utilized in the refineries. Some oil and other impurities find their way into the outlet. The settling tank of the plant of the Central Refining Co. is divided into two parts. One division received the wastes from the agitators and the other division received all other wastes, excepting part of the condenser water which is not passed through the tank. The tank effluent flowed through an open ditch to the river. It carried a yellowish brown coating and the banks of the ditch were coated with oil deposits. The separating tank of the Indian Eefining Co. plant is divided into two parts. The wastes treated are not kept separate. They may flow through either or both parts of the plant. The tank leaks and a new tank is under construction. The old tank will be repaired when the new one is in use.

During wet weather the pollution by wastes from the refineries is materially less than that by the crude oil from the oil wells, but it is entering the stream at all times. At the time of the visit there were no signs of pollution of the waters of Embarrass River above the outlet of the refineries. The wastes from the Central Refining Co. spread out over the entire width of the stream and only a short distance below the mouth of the ditch oil films are noticeable from bank to bank. Downstream the oil films clump together and form numerous large patches, dark brown in color. The wastes from the plant of the Indian Refining Co. are discharged into the river about one-fourth mile below the discharge from the Central Refining Co. The wastes fall a few feet where discharged into the river and form small patches of finely divided yellowish scum. These clump together into larger patches similar to those formed below the other refinery. A city sewer outlet is located between the outlets of the drains from the refineries. The sewage caused only a slight odor at the outlet and the stream flow was sufficient to prevent any nuisance downstream. During dry weather oil is deposited along the stream banks, or is retained by obstructions in the stream, the pollution growing less and less downstream. When rains occur all this retained oil is washed into the stream and the pollution extends farther downstream than during falling or low stages of the river.

The waters of Embarrass River and its tributary Indian Creek are objectionably polluted by crude oil from the oil wells and by wastes from the plants of the Central Refining Co. and the Indian Refining Co. The pollution is objectionable because of its effect upon fish life, the marring of the beauty of the stream and the deposition of the oil on overflow lands. Observation of the local game warden would indicate that the wastes have a serious effect upon fish life. Experiments conducted by M. C. Marsh, of the United States Bureau of Fisheries indicated that dilution of oil from water-gas wastes as great as 1 part of oil to 400,000 parts of water proved fatal to perch. AVhether the crude oil or wastes from refineries are more or less toxic than gas-house wastes cannot be stated. Even where the waste is sufficiently diluted as not to be destructive to fish life it still imparts a disagreeable taste to the flesh of the fish. The pollution by crude-oil wastes from the oil wells could be prevented by properly constructing and operating the wells, as is done on land west of the Baltimore and Ohio depot at Lawrenceville. The pollution entering from the refineries can be reduced or practically eliminated by careful operation of separating tanks and by earing for all surface drainage which does not pass through the tanks. If careful operation of the tanks now in use does not eliminate the pollution from these sources, the tank effluents should *be*, further treated. Probably treatment with lime and iron followed by sedimentation and filtration through coke filters might prove satisfactory.

LAWRENCEVILLE. Water supply.—(Bull. **9**, 25; **11**, 86; **12**, 93; **13**, 91.)

LEAF RIVER. Proposed water supply.—(Bull. **12**, 94.).

LE CLAIRE. Typhoid fever.—(Bull. **11**, 87.)

LELAND. Water supply.—(Bull. **12**, 95; **13**, 91.)

LEMONT (2,284). Water supply.—Visited November 27 and 28. Lemont is in the southwestern part of Cook County on the southeast side of the Chicago Sanitary and Ship Canal. A number of drains have been built of tile and stone. They discharge into the Illinois and Michigan Canal which passes through the village.

Waterworks were installed about 35 years ago. The source of supply was a flowing well 4 inches in diameter and probably about 1300 feet deep. Water was pumped into the distribution system by a duplex steam pump. Another well has been drilled 12 inches in diameter at the top, 6 inches in diameter at the bottom and over 2000 feet deep. About 600 feet of this well is cased. The wells enter rock a few feet from the surface. The 4-inch well is now equipped with an air lift with a 1½-inch air pipe extended to a depth of 100 feet. It yields about 58,000 gallons of water a day. Air is supplied by an electrically driven compressor. The deeper well is equipped with a 230,000-gallon electrically driven deep-well pump with the cylinder placed 85 or 90 feet below the top of the well. A 220,000-gallon electrically driven 7-inch by 8-inch triplex pump forces water into the distribution system. The suction pipe of the triplex pump is connected to the discharge of the deep-well pump and a branch lino connects a small wooden tank which serves as an equalizing reservoir when the deep-well pump is in operation. Water from the air lift discharges into this wooden tank from which it flows to the triplex pump. When the air lift is in operation it is necessary to open a by-pass between the discharge and suction pipes of the pressure pump to reduce its capacity. The pressure at the station is ordinarily about 60 pounds. A 30,000-gallon stone and concrete reservoir located on high ground is connected to the distribution system. Close to this reservoir is an auxiliary pumping station for use at times of fire. A 6-inch electrically driven centrifugal pump is provided to draw water from the reservoir and discharge it into the distribution system. The Public Service Company of Northern Illinois operates the pumping station charging 5 cents per 1,000 gallons of water pumped. Power is obtained from an electric transmission line from generating stations at Blue Island and Joliet.

Analyses indicate that some contaminating matter enters the wells. This may enter through fissures in the rock. Additional investigations are to be made. The water from the deeper well, which is generally used, has a mineral content of 1120, a total hardness of 272, and a content of iron of 1.7 parts per million.

LENA. Water supply.—(Bull. **11**, 88.)

LE ROY. Water supply.—(Bull. **10**, 136.)

LEWISTOWN. Water supply.—(Bull. **12**, 95.)

LEXINGTON. Water supply.—(Bull. **12**, 96.)

LIBERTYVILLE. Water supply and sewerage.—(Bull. **10**, 137.)

LINCOLN. Water supply.—(Bull. **10**, 138; **11**, 89.)
Sewerage.—(Bull. **12**, 96.)

LINCOLN, State school and colony. Water supply.—(Bull. **12**, 97; **13**, 92.)
Sewage disposal.—(Bull. **12**, 97.)

LINCOLN, State school and colony.—Visited October 18, to inspect the sanitary condition of the water supply and to see if typhoid and dysentery epidemics were being spread by the water. The sanitary inspection of the well on the grounds of the State school and colony show'ed that there was a possibility of it receiving pollution. This was born out by the results of laboratory examinations. A sanitary inspection and laboratory analyses of the Lincoln city water indicated a pure supply. No organisms which gave the characteristics of dysentery were isolated from either supply.

LITCHFIELD. Water supply.—(Bull. **9**, 26; **10**, 141; **11**, 89; **13**, 92.)
Typhoid-fever conditions.—(Bull. **11**, 90.)

LITTLE YORK. Water supply.—(Bull. **13**, 92.)

LOCKPORT. Water supply.—(Bull. **13**, 93.)
Inspection of private well.—(Bull. **13**, 93.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 26.)

LONDON MILLS. Water supply.—(Bull. **13**, 94.)

LOSTANT. Water supply.—(Bull. **11**, 90.)

LOUISVILLE (670).. Water supply.—Visited October 4. Louisville is in the central part of Clay County on the west bank of Little Wabash River.

Waterworks were installed in 1899-1900 for fire protection. The supply is obtained from Little Wabash River. The drainage area of the river above this place is 750 square miles. The natural flow has been sufficient to supply the limited demands. No dam has been built. The population on the drainage area above Louisville is about 29,000. The pumping station is on the bank of the river about 1,000 feet from the village square. Water is pumped into the distribution system by a 9-inch by 5⅝-inch by 12-inch duplex pump. Steam is supplied from an electric light plant. At low stages of the river the suction lift is 15 feet and at the highest known stage the pump was submerged. A 6-inch main extends from the station to the public square and a 4-inch main supplying 6 fire hydrants is laid around the square. There are 11 service connections. A 42,000-gallon steel tank supported on a 25-foot brick tower is connected to the distribution system.

The water is of unsatisfactory quality. It is turbid and is polluted by the sewage of Effingham, 24 miles north, the sewage of a small part of Mattoon, 50 miles north, and surface drainage from several small upstream communities. It is not used for drinking purposes.

LOVINGTON. Water supply.—(Bull. **12**, 97.)

LYONS (1,483). Water supply.—(Bull. **13**, 94.) Visited November 28. The cylinder of the deep-well pump has been lowered to a depth of 211 feet- and a connection has been made to the Berwyn distribution system in order that water may be taken from the Berwyn supply at times of great demand.

McHENRY. Water supply.—(Bull. **9**, 27.)

McLEAN. Proposed water supply.—(Bull. **13**, 94.)

McLEANSBOEO. Water supply.—(Bull. **10**, 147; **12**, 98; **13**, 95.)

MACKINAW. Water supply.—(Bull. **12**, 98.)

MACOMB. Water supply.—(Bull. **9**. 26; **12**, 99.)

MACON, County Almshouse. Sewage disposal.—(Bull. **11**, 90.)

MANSFIELD. Proposed water supply.—(Bull. **12**, 100.)

MANTENO. Water supply.—(Bull. **12**, 100.)

MAPLE PARK. Water supply.—(Bull. **13**, 95.)

MARENGO. Water supply.—(Bull. **11**, 91.)

MAEION (7,093). Water supply.—(Bull. **10**, 142; **12**, 101; **13**, 95.) Visited April 25 to examine a site for proposed test wells. The present water supply is limited and inadequate. It is proposed to put down test wells in the valley of Crab Orchard Creek south of the city. It is thought that a wide stretch of low ground in that vicinity may be underlain with sand and gravel deposits containing sufficient water to furnish wells of considerable yield. A farm well in that region struck sand and boulders at a depth of about 90 feet. The advisability of having test wells drilled by a company then employed at West Frankfort was being considered.

MAEION. Sewage disposal.—(Bull. **12**, 101; **13**, 96.) Visited April 25. Following a change in the city administration in 1915 the plans for sewage treatment previously approved by the State Water Survey were discarded and other plans were prepared. The sewage is to be treated in a septic tank the building of which is nearing completion.

MAEISSA. Proposed water supply.—(Bull. **12**, 102.)

MAEK. Water supply.—(Bull. **13**, 96.)

MAEOA. Water supply.—(Bull. **10**, 143.)

MAESEILLES. Water supply.—(Bull. **9**, 26; **13**, 96.)
Pollution of Illinois Eiver by Chicago Drainage Canal.—(Bull. 9, 26.)

MAESHALL. Water supply.—(Bull. **12**, 102.)
Typhoid fever.—(Bull. **12**, 103.)

MASCOUTAH. Water supply.—(Bull. **12**, 103.)

MASON CITY. Water supply.—(Bull. **12**, 104.)

MATTESON (461). Water supply.—(Bull. **12**, 105.) Visited November 29 and December 26. Matteson is in the southern part of Cook County. Plans for a system of sanitary sewers are being prepared for the village.

Waterworks were installed in 1914. The source of supply is a well 10 inches in diameter, 282 feet deep entering Niagara limestone. Water is pumped from the well into the distribution system by an electrically driven deep-well pump controlled by an automatic starter. The distribution system includes 0.8 miles of 8-inch pipe, 1.8 miles of 6-inch pipe, 31 fire hydrants, 39 valves and 19 service connections. The consumption during the past 6 months was estimated to be 90,000 gallons. A 1,000,000-gallon elevated steel tank on a 105-foot steel tower is connected to the distribution system. The waterworks cost about $22,000.

The water is of good sanitary quality. It has a mineral content of 684, a hardness of 534, and a content of iron of 1.2 parts per million.

MATTESON. Proposed sewerage.—(Bull. **12**, 105.)

MATTOON. Pollution of public water supply by improper disposal of city wastes.—(Bull. **10**, 144; **12**, 105.)
Proposed sewerage.—(Bull. **11**, 92.)

MATTOON. Microscopical survey of reservoir at Paradise near Mattoon. —Visited November 10. Mattoon is supplied with water for domestic use from wells. Water for certain commercial uses is taken from Paradise reservoir and used without purification. The reservoir was formed by damming Little Wabash Eiver. It has a capacity of 350,000,000 gallons. The surrounding land is mostly pasture and the inundated land was well cleared. At the time of the visit the water was somewhat muddy, due to recent rains, otherwise it was in excellent physical condition. Very few micro-organisms were found. Of the non-filamentous organisms there were about 30 per cc. Dissolved oxygen samples from the surface and bottom showed a saturation of 80 per cent or over. In addition to the micro-organisms a pond weed was noticed. This grew submerged but the wind seemed to break it loose and drive it into the shore. The condition of the reservoir did not indicate the necessity of treatment with chemicals at the time of the visit.

MAYAVOOD. Water supply.—(Bull. **10**, 146.)

MELROSE PARK. Water supply.—(Bull. **10**, 148.)

MELVIN. Water supply.—(Bull. **13**, 97.)

MENARD, Southern Illinois Penitentiary. Water supply.—(Bull. **11**, 92.)

MENDOTA. Water supply.—(Bull. **11**, 93.)
Sewerage—(Bull. **11**, 94.)
Treatment of gas-house wastes.—(Bull. **12**, 106; **13**, 97.)

MEREDOSIA. Pollution of Illinois River.—(Bull. **11**, 94.)

METAMORA. Water supply.—(Bull. **13**, 98.)

METROPOLIS. Water supply.—(Bull. **9**, 27; **11**, 94; **13**, 99.)

MILAN (727). Water supply.—Visited October 11. Milan is in Rock Island County on the southern bank of Rock River, about 4 miles south of Rock Island. There are no public sewers in the village.

Waterworks were installed in 1895. The source of supply is a 5-inch well 1175 feet deep penetrating St. Peter sandstone. In 1895 the pressure at the top of the well with no flow was 67 feet and the discharge at the ground surface was 350 gallons a minute. Recent tests show a flow of 100 gallons a minute at the ground surface. Well casings are replaced every few years. The casing now extends to a depth of 700 feet. Water flows directly from the well into an elevated wooden tank 16 feet high, 20 feet in diameter and supported on a 20-foot tower. A pump with a capacity of 200 gallons a minute against 60 pounds pressure driven by a gasoline engine is used to pump water from the well into the mains at times of fires. At the present time about 2 feet of water flows into the elevated tank during the night. In order to increase the supply water from the well is to be discharged into a small surface reservoir from which it will be pumped into the tank and distribution system by an electrically driven centrifugal pump with a capacity of 200 gallons per minute against 65 pounds pressure. There are no meters. The maximum charge for water is $5.00 per year.

The water is of good sanitary quality.

MILFORD. Water Supply.—(Bull. **11**, 95.)
Sewerage.—(Bull. **11**, 95.)

MILLEDGEVILLE (630). Water supply.—Visited October 13. Milledgeville is in the southwestern part of Carroll County on the drainage area of Elkhorn Creek, a tributary of Rock River.

Waterworks were installed about 20 years ago. Water is obtained from two wells from 250 to 300 feet deep in the western part of the village. The wells are equipped with deep-well pumps which discharge into two steel pressure tanks 8 feet in diameter and 36 feet long. The pressure is maintained between 45 and 100 pounds. Power to operate the pumps and a small air compressor is furnished by a 15-horsepower gasoline engine. A distribution system is connected with the pressure tanks and discharge lines from the well pumps. It is proposed to install electric lights in the village and consider using electric power for pumping water. Several possible arrangements were recommended for consideration.

The water is of good sanitary quality. It has a mineral content of 352 and a hardness of 323 parts per million. It contains no iron.

MINIER (690). Water supply.—Visited December 13. Minier is in the eastern part of Tazewell County on the drainage area of Sugar Creek, a tributary of Sangamon River.

Waterworks were installed in 1891. Water is obtained from a well 8 inches in diameter and 143 feet deep extending through 14 feet of sand and fine gravel. The static water level is at a depth of 75 feet. Water is pumped from the well into the distribution system by a steam head deep-well pump with a 6-ineh by 36-inch cylinder at a depth of 130 feet. Pumping at an estimated rate of 150 gallons per minute the water level is lowered to the pump cylinder. There are 1.8 miles of 2-inch, 4-inch and 6-ineh mains, 18 hydrants, and 8 valves in the distribution system. A 46,000-gallon elevated wooden tank on an 80-foot steel tower is connected to the mains. Nearly every person in town uses water from the public supply. The average daily consumption is about 75,000 gallons. The plant is operated in connection with a municipal electric lighting plant.

The water is of good sanitary quality. It has a mineral content of 361, a total hardness of 292, and a content of iron of 1.5 parts per million.

MINONK. Water supply.—(Bull. **12**, 107.)
Disposal of sewage.—(Bull. **12**, 107; **13**, 100.)

MINOOKA. Water supply.—(Bull. **11**, 95.)
Sewerage.—(Bull. **11**, 96.)

MOKENA. Water supply.—(Bull. **13**, 100.)

MOLINE. Water supply.—(Bull. **13**, 100.)
Additional sewerage.—(Bull. **11**, 96.)
Sanitary survey of Mississippi River.—(Bull. **9**, 27.)

MOMENCE. Water supply.—(Bull. **11**, 97.)
Sewerage.—(Bull. **11**, 97.)

MONEE. Water supply.—(Bull. **13**, 103.)

MONEY CREEK TOWNSHIP. Typhoid fever.—(Bull. **13**, 104.)

MONMOUTH. Water supply.—(Bull. **10**, 149.)

MONTGOMERY. Sewage disposal.—(Bull. **12**, 108.)

MONTICELLO. Water supply.—(Bull. **10**, 150; **12**, 109.)

MORRIS. Water supply.—(Bull. **12**, 109.)
Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **9**, 27.)

MORRISON. Water supply.—(Bull. **12**, 110.)

MORRISONVILLE. Water supply.—(Bull. **11**, 98.)

MORTON. Water supply.—(Bull. **13**, 106.)

MORTON GROVE (836). Water supply.—Visited November 29. Morton Grove is a suburban community in the northern part of Cook County on the drainage area of the north branch of Chicago River. Poehlmann Brothers, florists, operate their own water supply. A sewer system serves nearly all of the residences. The sewage is treated in Imhoff tanks, the effluent from which flows into the river.

Waterworks were installed in 1914. The source of supply is a well 1468 feet deep. The upper 125 feet is 10 inches in diameter and the remainder is 8 inches in diameter. The well is cased to a depth of 1100 feet. Water is pumped from the well into the distribution system by an electrically driven deep-well pump with the cylinder placed at a depth of 110 feet. The static water level is 74 feet below the surface. The distribution system includes 3.2 miles of 6-inch and 8-ineh mains, about 40 hydrants, and about 100 service connections. An elevated steel tank of 50,000 gallons capacity, with the top of tank 139½ feet above foundations, is connected to the distribution system. The distribution systems of the village and Poehlmann Brothers are connected. The village waterworks cost about $36,000.

The water is of good sanitary quality. It has a mineral content of 636, a hardness of 377, and a content of iron of 1.5 parts per million.

MOUND CITY. Water supply.—(Bull. **13**, 106.)
Proposed Sewerage.—(Bull. **13**, 106.)

MOUNDS. Water supply.—(Bull. **9**, 27; **11**, 98.)
Sewerage and sewage-treatment plant.—(Bull. **13**, 107.)

MOUNT CARMEL. Water supply.—(Bull **9**, 27; **12**, 111; **13**, 108.)

MOUNT CARROLL. Water supply.—(Bull. **11**, 100.)

MOUNT MORRIS. Water supply.—(Bull. **11**, 100.)

MOUNT OLIVE. Water supply.—(Bull. **10**, 151.)

MOUNT PULASKI. Proposed additional water supply.—(Bull. **11**, 101; **12**, 113.)
Sewerage.—(Bull. **12**, 113.)

MOUNT STERLING. Water supply.—(Bull. **11**, 102.)
Proposed sewerage.—(Bull. **11**, 101.)

MOUNT VERNON. Water supply.—(Bull. **10**, 152; **11**, 102; **12**, 113; **13**, 109.)

MT. VERNON. Microscopical survey of reservoir.—Visited September 30. A microscopic survey of the sources of the city's water supply was made. The city is provided with filtered water obtained from three sources, an old reservoir, a new reservoir, and a small stream known as Casey Fork. Water is pumped to the filters from the old "lower" reservoir. The quantity of water available from this source has decreased to such an extent that it is necessary to supplement it with water from Casey Fork. The new or "upper" reservoir, originally designed for emergency use, now constitutes a regular source of supply. As there is no pipe line connecting this reservoir with the other, water is allowed to flow through a discharge pipe in the dam into Casey Fork from where it may be pumped to the lower reservoir.

The old reservoir, constructed about 1870, has a drainage area of about 525 acres and an estimated capacity of 36,000,000 gallons. The maximum depth is about 20 feet. Two or three springs in the bottom of the reservoir have a bearing on the microscopic flora present. The banks are mostly yellow clay. This smaller reservoir constitutes only a sedimentation basin for water that is pumped into it. Moderately heavy growths of filamentous algae were evident in many places near the banks. A fine green "mealy" precipitate in the water was very noticeable. Microscopic examination showed the algae growth in the reservoir to be rather large, considering the prevailing cold weather conditions. Organisms that under proper temperature and weather conditions might be expected to cause bad odors and tastes as well as troubles in filter operation were present. The dissolved oxygen ranged from 85.5 to 99.0 per cent of saturation.

The upper reservoir, 4½ miles north of the city, was constructed in 1909. When full it covers about 80 acres. It has a maximum depth of 18 feet, and an estimated capacity of 360,000,000 gallons. The catchment area comprises about 2,7 square miles consisting of woods and cultivated lands. The banks are chiefly yellow clay and at the time of the visit appeared remarkably free of any growth below the surface. The supply of water is said to considerably exceed the demand so that the banks below high water are seldom exposed. Practically no swampy areas could be seen along the banks. A very luxuriant growth of what were described as "deep sea flags" or water lilies occupies a large section of the reservoir. They appeared to be in a very healthy growing condition, and showed no evidences of algae growth. The water in this reservoir was in excellent physical condition. The microscopic examination showed the presence of anobena and dinobryon, but in fairly small numbers.

Filamentous algae were quite abundant near the dam in Casey Fork, and the unnatural conditions of flow maintained in the stream render it probable that during hot weather periods very troublesome growths might occur. Treatment of the water for the removal of algae was not recommended because of the approach of cold weather but it is probable that the growths may develop at another season, and that they would require treatment.

MOWEAQUA. Water supply.—(Bull. **11**, 99.)

MURPHYSBORO. Water supply.—(Bull. **10**, 155; **11**, 103; **12**, 114; **13**, 109.)

NAPERVILLE. Water supply.—(Bull. **13**, 109.)

NAUVOO. Water supply.—(Bull. **10**, 157.)

NEOGA. Proposed water supply.—(Bull. **13**. 110.)

NEW ATHENS. Proposed water supply.—(Bull. **10**, 158.)

NEW WINDSOR. Typhoid fever.—(Bull. **11**, 103.)
Proposed water supply.—(Bull. **11**, 104.)

NEWTON. Water supply.—(Bull. **10**, 159; **13**, 111.)

NOKOMIS. Water supply.—(Bull. **11**, 105.)
Proposed sewerage and sewage treatment.—(Bull. **12**, 114.)

NORMAL (4,024). Water supply.—(Bull. **10**, 159.) Visited February 1 and 8. The source of water supply is a 12-inch well 204 feet deep which was drilled in 1913. Water-bearing strata are entered at depths of about 180 feet and 195 feet. The well is cased to the bottom where a 20-foot Cook screen has been placed. The static water level is at a depth of 133 feet. The well is equipped with 600-gallon a minute electrically driven vertical centrifugal pump. The pump is run 12 to 13 hours a day. Two 180-foot wells formerly in use are still available. After operating about half an hour their discharge was so small it was almost impossible to collect a sample. Nothing definite has been done with regard to increasing the available supply. Two new 900,000-gallon electrically driven centrifugal service pumps were installed and other improvements were made in 1913.

NORTH CHICAGO. Sewerage.—(Bull. **9**, 28; **11**, 105.)

NOETH CRYSTAL LAKE. Water supply.—(Bull. **12**, 116.)

OAK PARK. Typhoid fever.—(Bull. **13**, 112.)

OAKLAND. Water supply.—(Bull. **12**, 116.)

OBLONG. Proposed water supply.—(Bull. **13**, 112.)

ODELL. Water supply.—(Bull. **12**, 116; **13**, 113.)

ODELL. Test of operation of apparatus for removal of hydrogen sulfide from the water supply.—Visited January 6, 7, and 8 at the request of village officials to determine the efficiency of the aerator installed in the reservoir of the public water supply to remove hydrogen sulfide from the water.

The water is highly mineralized and has a salty taste but a more troublesome constituent is the hydrogen sulfide it contains. This amounts to 6 to 7 parts per million as the water comes from the wells. A reduction of from 50 to 75 per cent was obtained by aeration and consequently the installation of an aerating device to be located in a surface reservoir was recommended and the device was built. It consists of a series of five sheet-metal trays placed one foot apart, one above the other and varying in dimensions from 18 inches square at the top to 5½ feet square at the bottom. The trays are punched with 3/16-inch holes spaced 1¾, inches on centers. The edges of the trays are turned up about one inch. The discharge pipe from the pump extends about 6 inches above the top tray and 10½ feet above high water in the reservoir. Water is pumped from the well over the aerator from where it falls into the reservoir and is then pumped to an elevated tank connected to the distribution system.

Testing the aerator consisted mainly of making hydrogen sulfide and dissolved oxygen determinations in the water taken directly from the well and from points in the distribution system.

The water in the well contained 6.5 parts per million of hydrogen sulfide and no dissolved oxygen. After passing over the aerator it contained 8 parts per million of dissolved oxygen and was 80 per cent saturated. The hydrogen sulfide was reduced to 4 parts' per million. This loss is undoubtedly due to disappearance into the atmosphere by mechanical, aeration. This is evidenced by the odors of hydrogen sulfide in the vicinity of the pumping station. These odors have not been sufficiently strong to create a nuisance.

It was found that the water after it is pumped to the elevated tank was practically free from hydrogen sulfide and about 50 per cent saturated with oxygen. Examinations made of water from taps showed practically no hydrogen sulfide present. Very little if any odor could be detected and the water was only slightly turbid.

A comparison of results obtained before and after installation of the aerator shows that the aerator is giving excellent results, that the water is receiving adequate aeration, and that the hydrogen sulfide is practically all removed. This is also shown by the decrease in the number of complaints. The improvement is quite generally commented upon and people who previously did not use the water are now using it.

OHIO (527). Water supply.—Visited October 20 and December 29. Ohio is in the northern part of Bureau County on the drainage area of West Bureau Creek. There is no sewer system.

Waterworks were installed more than 20 years ago. A deep well was drilled and equipped with a steam-driven deep-well pump and a distribution system and elevated tank were built. The original well has been abandoned and two other wells have been drilled in glacial drift which is 412 feet deep. One well is 385 feet deep and has a-24-foot screen. It is equipped with a steam-head deep-well pump of about 30 gallons a minute capacity. The other well is 6 inches in diameter and 388 feet deep. In the bottom is a 34-foot screen of No. 60 gauze wire. Considerable sand entered this well. A No. 6 Johnson screen has been placed in the bottom of the well inside the other screen. It was necessary to use a screen 2 inches in diameter in order to go through a 3-inch pipe attached to a pump cylinder wedged in the well. This inner screen has not materially lessened the troubles caused by sand.

The well is equipped with an electrically driven 60-gallon a minute deep-well pump with a 4¼-inch by 18-inch cylinder placed at a depth of 320 feet. When pumping only from the other well the water level in this well is 260 feet below the surface. The trouble caused by sand might be lessened by decreasing the rate of pumping. A larger well would give less trouble from this source. The well pumps discharge directly into the distribution system to which a 24,000-gallon elevated wooden tank on a 90-foot steel tower is connected. The Illinois Northern Utilities Co. operates the pumping station in connection with an electric light plant. They are soon to furnish electric current from Sterling and discontinue the use of the local power plant. It was recommended that when that change is made the village erect a fireproof pumping station, build a surface reservoir, install an engine to be used in case of emergency, and drill another well unless pumping the wells now in use at lower rates proves practicable.

The water is of good sanitary quality. It has a mineral content of 362, a total hardness of 180, and content of iron of 5 parts per million.

OLNEY. Water supply.—(Bull. **11**, 106.)
Sewerage and sewage disposal.—(Bull. **12**, 117.)

ONARGA. Water supply.—(Bull. **11**, 107.)
Proposed sewerage.—(Bull. **12**, 118.)

OREGON. Water supply.—(Bull. **11**, 107.)
Pollution of creek by wastes from a silica sand-washing plant. —(Bull. **13**, 113.)

OTTAWA. Water supply.—(Bull. **9**, 28.)

PALATINE. Water supply.—(Bull. **12**, 119.)
Sewage treatment.—(Bull. **10**, 161; **12**, 119.)

PANA. Water supply.—(Bull. **9**, 29; **10**, 161; **13**, 114.)
Pollution of a tributary of Beck Creek.—(Bull. **13**, 115.)
Sewage disposal.—(Bull. **12**, 120; **13**, 115.)

PANA (6,055). Typhoid-fever epidemic—(Bull. **12**, 120.) Visited May 4 to May 9 in response to a letter from H. N. Schuyler, mayor, stating that there was an epidemic of typhoid fever, and that some suspicion was attached to the public water supply as a possible source of infection.

From April 16 to the close of the investigation on May 9 there had developed 36 cases of typhoid fever, and one death had resulted. One of the patients had been infected away from Pana. The other 35 cases were distributed among 33 families which had a total membership of 149. In only 2 families was there more than one case of typhoid fever. The cases were about evenly distributed among males and females and persons of all ages were involved. The patients had not come together at any general gathering. About half of them were school children. They were of different ages and attended different grades and different schools. About two-thirds of the patients resided in the southeast part of the city and most of the others resided in the central part.

The public water supply is obtained in part from wells northwest of the city and in part from an impounding reservoir on Bett 's Creek east of the city. Water from the reservoir is treated in rapid filters. There are neither sedimentation basins nor proper chemical preparation-and-feed devices and the water is not sterilized. The results obtained from the treatment plant have not been entirely satisfactory and samples of filtered water have on numerous occasions shown evidence of contamination. It is customary to use the surface water during the day and pump from the wells during the night. The supply from the wells is inadequate to meet the demands and is harder than the surface water. The water consumption of the western part of the city is probably not sufficient to use all of the well water pumped into the mains during the night and probably very little filtered water is drawn from taps in that part of the city.

Of the 35 patients, 21 were sure that they had used city water, 8 were not sure and 6 stated definitely that they had not used water from the city supply. Thus, though a majority of them used the city water there were enough patients that had not been so doing to indicate that there must have been some other agent of infection. There were 5 patients who had used water from the so-called Jail well, and 32 who used water from wells at home or other private wells. Although many of the wells were not constructed so that they would prevent contamination there is no reason to believe that so many would become infected with typhoid germs at the same time from these wells, and thus cause an epidemic of typhoid fever.

There are four large dairies at Pana and there are several persons who keep a few cows and sell milk to neighbors. Of the 35 typhoid-fever patients the number among the customers of the four large dairies was as follows: 28, Pana Ice Cream Company dairy; 6, Sugar Creek Creamery; 2, G. C. Schloz; 3, E. F. Lee. There was one patient among the customers of each of four small dairies. All six patients who were customers of the Sugar Creek Creamery dairy were also customers of the Pana Ice Cream Company dairy. Seven of the customers of the other dairies were not customers of the Pana Ice Cream Company but all had used milk from that dairy at restaurants or soda fountains. The records of the milk used showed that the milk supply of the Pana Ice Cream Company must have been the cause of the epidemic. If the public water supply had been the cause it would be reasonable to suppose that more cases would have developed among the customers of some of the other dairies, especially the Scholz dairy, which supplied 210 customers among whom there were only 2 patients. The Pana Ice Cream Company maintains no wagon delivery. They have two establishments in the eastern part of the city where most of the cases of typhoid fever occurred. Their principal product is ice cream which is shipped to neighboring cities. Milk is sold to customers who come to their establishment. The company was purchasing milk from 14 farmers at the time of the epidemic. The first milk received was placed in a can in an ice box and sold to customers during a day. All the ice cream was made at one of the plants and the records of the cases of typhoid fever and the absence of cases in neighboring cities where ice cream was supplied, showed that the ice cream was not the cause of the typhoid. The customers brought their own pails and milk was dipped from the can in the ice box. During an inspection of the plant, an attendant was seen to pour milk into a pail while holding the pail directly over the milk can and drippings fell back into the can. In this manner it would have been possible to infect all of the milk in the' can. Since there had been many eases of typhoid fever in Pana during the previous year there were undoubtedly carrier cases and milk utensils from their homes may have been responsible for the infection of the milk supply.

When it was ascertained that the epidemic was not caused by the public water supply but was caused by milk and that products of the dairies involved were shipped to a number of cities the State Board of Health was notified. The information that had been obtained was supplied to them and they undertook the further investigation of the epidemic and inaugurated methods of preventing its further spread. The city council was urged to have a milk ordinance passed and to have the water-purification plant completed.

PARIS. Water supply.—(Bull. **10**, 164.)

PARK RIDGE. Typhoid fever.—(Bull. **13**, 116.)

PAW PAW (709). Water supply.—Visited March 29. Paw Paw is in the southeastern part of Lee County on the drainage area of Fox River.

Waterworks were installed in 1891. Water was pumped from a well by a windmill. An elevated wooden tank was connected to the distribution system. A well 1018 feet deep is the present source of supply. It penetrates 454 feet of drift, 296 feet of limestone, 135 feet of shale, 133 feet of sandstone (St. Peter) and enters limestone. A pit 5 feet deep surrounds the top of the well. The well casing, however, extends up to the pump room floor.

Water is pumped from the well by a steam-head deep-well pump with a 5¾-inch by 36-inch water cylinder. Water is generally pumped from the well into a collecting reservoir but it is possible to pump directly into the distribution system. The collecting reservoir has brick walls and a conical shingled roof. The walls are not water-tight. Water is pumped from this reservoir into the distribution system by a 340,000-gallon duplex pump. The pump is operated about 4½ hours a day. It is equipped with an automatic pressure governor. A gage at the station registers 52½ pounds when the elevated tank is full and generally registers not less than 50 pounds.

A 60,000-gallon elevated steel tank on high ground near the center of the village is connected to the distribution system. There are 216 service connections in use. The consumption is estimated at about 68;000 gallons a day.

The water is of good sanitary quality. It has a mineral content of 297, a hardness of 220, and a content of iron of 1.5 parts per million.

PAXTON. Water supply.—(Bull. **10**, 165.)

PEARL. Water supply.—(Bull. **12**, 120.)

Pollution of Illinois River.—(Bull. **11**, 108.)

PEARL CITY (485). Water supply.—Visited October 14. Pearl City is in the southwestern part of Stevenson County on Yellow Creek, a small branch of Pecatonica Eiver. There are no public sewers in the village.

Waterworks were installed about 20 years ago. A well was drilled on high ground in the village, an elevated wooden tank was built, and a distribution system was constructed. On account of inadequate yield the well was abandoned and water was purchased from a creamery company. The old tank has been replaced and in 1910 two wells that are still in use were drilled on low ground near the creek. The wells penetrate soil, clay and quicksand, and terminate in gravel at a depth of 40 feet. One well is 6 inches and the other 8 inches in diameter. Water is pumped from the wells into the distribution system by a triplex pump of 120,000 gallons capacity. The suction pipes extend 32 feet into the wells. The static water level is 15 to 18 feet below the surface. One "well can not continuously supply the capacity of the pump. The distribution system includes about 780 feet of 6-inch, and 5,300 feet of 4-inch pipe, some smaller pipe, 16 hydrants, 5 valves, and 66 service connections. The system does not provide very good fire protection. An elevated wooden tank on a 70-foot steel tower is connected to the distribution system. The water consumption is estimated at about 15,000 gallons a day.

The water is of good sanitary quality. In order to decrease chances of pollution it was recommended that the tops of the wells be made more nearly water-tight and that no sewage be discharged near the wells. The water has a mineral content of 722, a hardness of 570, and a content of iron of 0.6 parts per million.

PECATONICA. Water supply.—(Bull. **11**, 108; **13**, 116.)

PEKIN. Water supply.—(Bull. **10**, 166.)

Pollution of Illinois River by Chicago Drainage Canal.—(Bull. **11**, 108.)

PEORIA. Water supply.—(Bull. **9**, 29; **11**, 109.)

PEORIA, State hospital. Water supply.—(Bull. **10**, 166.)

PEORIA. Microscopical survey of reservoir.—Visited October 5. Water, derived from wells in drift along the western bank of Illinois River, is pumped directly into the. distribution system. A reservoir connected to the system serving as an equalizing storage basin, covers approximately three acres and has a capacity of about 18,000,000 gallons. The depth varies from 21 to 39 feet. It is kept full of water under ordinary conditions.

The physical appearance of the water in the reservoir was very good. There were very few microscopic organisms present, the average number of total organisms per cc. being 80 on 12 samples examined. Copper sulfate treatment was not advised because of the probable approach of cold weather conditions.

Diatoms and other organisms capable of producing tastes or odors were present which under suitable weather conditions might develop into troublesome growths. It is understood that the water company provides proper treatment for the water in hot weather. A sample of moss from the bottom of the reservoir was found to be of the genus "Bryum." The average per cent saturation of water with dissolved oxygen varied from 89 to 95 on the surface and from 79 to 87 at a depth of 20 feet.

PEORIA HEIGHTS. Water supply.—(Bull. **9**, 29; **11**, 109.)

PEOTONE. Water supply.—(Bull. **11**, 109.)

PERU. Water supply.—(Bull. **11**, 109; **13**, 116.)

PETERSBURG. (2,587). Water supply.—(Bull. **10**, 167.) Visited August 19 to inspect changes made following recommendations made by the State Board of Health. A connection between the suction pipe of a pump used to pump river water to a railroad tank and a suction pipe to the well had been discarded. A connection between the discharge pipe of this pump and the city water pipe had not yet been abandoned as necessary fittings had not been received. Other improvements recommended have not been made and the recommended ordinance that would have required privies to be abandoned where sewers were accessible has not been placed in force. The sanitary conditions have been little improved over what existed at the time of the sanitary survey in the fall of 1915.

PINCKNEYVILLE. Water supply.—(Bull. **11**, 110.)

PIPER CITY. Water supply.—(Bull. **11**, 111; **12**, 122.)

PITTSFIELD. Water supply.—(Bull. **11**, 111.)
Disposal of sewage at high school.—(Bull. **13**, 117.)

PLAINFIELD. Water supply.—(Bull. **11**, 112.)
Sewage disposal.—(Bull. **12**, 122.)

PLANO. Water supply.—(Bull. **9**, 29.)
Sewerage and sewage disposal.—(Bull. **12**, 122.)

PLEASANT HILL. Typhoid fever.—(Bull. **11**, 113.)

POLO. Water supply.—(Bull. **11**, 113.)

PONTIAC. Water supply.—(Bull. **9**, 30; **11**, 113; **13**, 117.)
Sewage disposal.—(Bull. **12**, 123; **13**, 118.)

PORTLAND. Water supply.—(Bull. **11**, 115; **13**, 118.)

PRINCETON. Water supply.—(Bull. **12**, 124.)
Sewage disposal.—(Bull. **12**, 125.)

PRINCEVILLE. Proposed water supply.—(Bull. **11**, 116; **12**, 126.)

PROPHETSTOWN (1,083). Water supply.—Visited December 28. Prophetstown is in the central southern part of Whiteside County on the south bank of Rock River. A large part of the village is sewered with a combined system of sewers which discharge into Rock River.

Waterworks were installed in 1904. Water is obtained from 2 wells about 60 feet apart located about 200 feet from the southern bank of Rock River. One well is 8 feet and the other 16 feet in diameter. Each well is 16 feet deep, is walled with brick banked around the outside with earth to the high water level of the river, and is covered with a conical wooden roof. The water level in the wells varies with the water level in the river but ordinarily when not pumping it is from 6 to 8 feet below the surface. In dry weather with continued pumping the water level is drawn down to the inlet of the suction pipes about one foot above the bottom of the wells. Water is drawn from the wells and discharged into the distribution system by an electrically driven triplex pump with a capacity of 240,000 gallons. An automatic device regulated by the height of water in the elevated tank starts and stops the pump. A gasoline-engine-driven triplex pump is available for use in case of emergency. There are 2½ miles of 4-inch, 6-inch, and 8-inch mains in the distribution system. A 63,000-gallon elevated steel tank located on high ground near the wells and pumping station is connected to the distribution system. The pressure maintained at the pumping station is ordinarily about 60 pounds. The waterworks cost about $23,000. Electric current is purchased from the Illinois Northern Utilities Co. It is understood that a cemetery 250 to 300 feet south of the wells is to be extended. It would not be advisable to extend the cemetery toward the wells.

The water was of good sanitary quality. Samples should be analyzed when the ground surrounding the well is flooded. The water has a mineral content of 292, a hardness of 250, and a content of iron of 0.05 parts per million.

QUINCT. Water supply.—(Bull. **9**, 30; **11**, 116; **12**, 126.)

RANKIN (858). Proposed water supply.—(Bull. **13**, 118.) Visited July 18 and August 23 to examine and assist in a pumping test of a well proposed as a source of public supply.

A bond issue for waterworks purposes was favorably voted upon in 1915. The waterworks will comprise a drift well equipped with a deep-well pump, a collecting reservoir, a triplex pump for high service, two pressure tanks and a-distribution system. The well is 270 feet deep. It is equipped with a 16-foot No. 30 Johnson screen. The well penetrates 119 feet of clay and 151 feet of sand and gravel, part of which was recorded as cemented sand. Water was encountered in a sand layer between depths of 119 and 128 feet and in sand and gravel between depths of 222 and 230 feet, and below a depth of 256. A test of the yield was made after the well had penetrated the water-bearing stratum between depths of 222 and 230 feet. The static water level was 35 feet below the surface. The working barrel was placed at a depth of only 50 feet, and little water was secured. The static level of the water from the lower vein is 50 feet below the surface. A pumping test was run with a pump cylinder placed at a depth of 226 feet with a suction pipe extending to a depth of 249 feet. After pumping 15 hours or more with only a few short stops the pump drew air and the yield of water was between 60 and 70 gallons a minute.

The water is of good sanitary quality. It has a mineral content of 424, a hardness of 326, and a content of iron of 1.6 parts per million. The water is not as hard as water from a 306-foot well in the village.

RANKIN. Proposed sewerage.—(Bull. **11**, 117; **12**, 127.)

RANTOUL. Water supply.—(Bull. **10**, 168.)

RED BUD. Water supply.—(Bull. **12**, 127; **13**, 119.)

REDDICK. Proposed water supply.—(Bull. **11**, 117.)

RIVER FOREST. Water supply.—(Bull. **10**, 169.)

RIVERDALE. Water supply.—(Bull. **13**, 119.)

RIVERSIDE. Water supply.—(Bull. **11**, 118.)

ROANOKE. Water supply.—(Bull. **11**, 119; **13**, 120.)

ROBERTS. Water supply.—(Bull. **13**, 120.)

ROBINSON. Water supply.—(Bull. **9**, 30; **12**, 127.)

ROCHELLE. Water supply.—(Bull. **11**, 120.)
Sewerage.—(Bull. **11**, 120.)

ROCK FALLS. Water supply.—(Bull. **13**, 121.)

ROCK ISLAND. Water supply.—(Bull. **9**, 30.)
Disposal of gas wastes.—(Bull.**12**,128,225-8; **13**, 124.)

ROCK ISLAND, Arsenal. Water supply.—(Bull. **11**, 120; **13**, 125.)

ROCKDALE. Water supply.—(Bull. **13**, 125.)

ROCKFORD. Water supply.—(Bull. **10**, 170.)

ROODHOUSE. Water supply.—(Bull. **11**, 121.)

ROSEVILLE. Sewerage.—(Bull. **13**, 126.)

ROSSVILLE. Water supply.—(Bull. **10**, 172.)

RUSHVILLE. Water supply.—(Bull. **9**, 30; **12**, 128.)

ST. ANNE. Water supply.—(Bull. **13**, 126.)
Proposed sewerage.—(Bull. **11**, 122.)

ST. CHARLES. Water supply.—(Bull. **9**, 30; **12**, 129.)

ST. ELMO. Water supply.—(Bull. **10**, 174.)

ST. PETERS (313). Typhoid-fever epidemic.—Visited February 8 and 9. An outbreak of typhoid fever occurred in December 1915. A man became infected with the disease while on a trip to Peoria, Bloomington, and Sullivan, on December 5, 6, and 7. Just how or where he became infected was not ascertained. The patient was sufficiently ill on December 22 to quit work. His illness was never diagnosed as typhoid fever. The patient died on December 31 a few hours after an operation was performed following a diagnosis of appendicitis.

Cases occurred in five houses scattered through the village! The patients did not use a common water supply or a common milk supply. Locally some suspicion had been attached to water, as the source of infection. The wells from which the water supply is obtained at St. Peters are nearly all poorly constructed and subject to contamination but no information obtained showed that the infection was spread by water from wells. One dairy furnished milk to three of the patients but no ease of sickness occurred ,at the dairy, in the local hotel, or at eight other households supplied by this dairy. The spread of the fever was favored by the fact that the first patient's sickness was not recognized as typhoid, and consequently the necessary precautions were not followed. Even in the instance of other eases, proper sanitary precautions, especially in regard to disposal of discharges, were not being taken at the time of the investigation. Following instructions, however, conditions were being materially improved before the investigation ended.

The first patient was visited frequently by his brother. This brother was taken sick on January 12 and died on January 26.

A young man visited the first patient on December 28 and attended the wake of that patient on January 2. He was taken ill on January 15, eighteen days after the visit to the first patient, and died on January 29.

A niece of the first patient visited him on December 25 and worked in his household from December 28 to January 2. On January 18 she was taken sick and she died on February 8.

The wife of the second patient, sister-in-law of the first patient, visited the first patient on several occasions. She was taken sick nine days after her husband, probably from infection received in her own household.

A sister of the young lady taken sick January 18 had slept with her in the beginning of her illness. She had also visited the first patient. It is probable that she was infected from her sister.

A girl was found to have the fever on January 23. She had worked in the home of the first patient until January 8, after which she worked at the home of another family until January 14, when she went to work at the home of the first patient's brother, who had become ill.

On February 2, an eight-year-old girl was taken ill. She was a member of the family for whom the girl mentioned above worked from January 8 to January 14, after having worked at the home of the first patient.

The infection spread from the first patient who contracted the disease while on a trip out of St. Peters. Four or five other persons were infected by contact with him or with utensils or clothing used by him. The remaining two or three cases resulted from contact with persons who had become infected from the first patient.

SALEM. Water supply.—(Bull. **11**, 123.)

Proposed sewerage and sewage treatment.—-(Bull. **11**, 123; **13**, 127.)

Disposal of sewage from high school.—(Bull. **13**, 128.)

SAN JOSE. Water supply.—(Bull. **12**, 131.)

SANDWICH. Water supply.—(Bull. **9**, 30; **12**, 130.)

Sewage treatment.—(Bull. **13**, 128.)

SANGAMON, County poor farm. Proposed sewage treatment.—(Bull. **11**, 123).

SAVANNA (3,691). Water supply.—(Bull. **11**, 124.) Visited October 12. Water is obtained from two flowing wells. One well is 5 inches in diameter and 1435 feet deep. The other one is 8 inches in diameter and 1500 feet deep. Recently the water consumption has been 680,000 to 700,000 gallons a day which is about equal to the yield of the wells. It is proposed to drill a new well. With the little information available it does not seem advisable to drill another well less than 8 inches in diameter. The yield of a 10-inch well would probably be less than 7 per cent greater than that from an 8-inch well and the yield from a 12-inch well would probably be from 2 to 4 per cent greater than the yield of a 10-inch well. If wells should ever have to be pumped large wells can be pumped with larger and more efficient pumps than can the smaller wells. A well on comparatively low ground will save some cost in drilling. If the city would arrange to determine the yield and pressure at various rates of flow of the existing wells, new work could be undertaken much more intelligently.

SEARS. Proposed water supply.—(Bull. **12**, 131; **13**, 129.)

SECOR. Water supply.—(Bull. **13**, 129.)

SHAWNEETOWN. Flood conditions on Ohio River.—(Bull. **11**, 124.)

SHEFFIELD. Water supply.—(Bull. **12**, 131;)

SHELBYVILLE. Water supply.—(Bull. **11**, 125:)

SHELDON. Water supply.—(Bull. **11**, 125.)

SILVIS. Water supply.—(Bull. **10**, 173.)

SOMONAUK. Water supply.—(Bull. **13**, 129.)

Stream pollution.—(Bull. **13**, 130.)

SOUTH BELOIT. Pollution of Turtle Creek.—(Bull. **13**, 130.)

SPARTA. Proposed water supply.—(Bull. **12**, 132.)

Typhoid fever.—(Bull. **12**, 132.)

SPARTA (3,081). Proposed sewerage.—Visited January 14, at the request of the Randolph Club of that city, to give a talk on sanitary conditions and the need of sewerage at Sparta. The city has good natural drainage.

The consulting engineer states that it would be possible to sewer the entire city and have only one outlet. This would be into a tributary of Marys

River in the southeast end of the city. The tributary has a drainage area above the proposed outlet of about four square miles and has no flow during dry weather. The engineer estimates that a complete sanitary sewer system and sewage settling tank would cost about $50,000. A mass meeting was attended at which the present sanitary conditions were discussed and the need of a sewer system was pointed out. The difference between separate and combined systems of sewers and the advantages and use of each were explained A separate system for Sparta was advised. The necessity of installing a sewage-treatment plant on account of the sewage discharging into a watercourse having a small drainage area was pointed out. Different devices and forms of sewage-treatment plants were explained and illustrated with lantern slides. A motion was passed that it was the sense of that meeting that the question of installing a sewer system should be further considered and that another meeting for this purpose should be held in the immediate future.

SPRING VALLEY. Water supply.—(Bull. **11**, 126.)
Pollution of Illinois Eiver.—(Bull. **11**, 126.)

SPRINGEIELD. Water supply.—(Bull. **9**, 31; **11**, 126.)
Sanitary conditions of State fairgrounds.—(Bull. **12**, 132.)
Pollution of Sangamon Eiver.—(Bull. **13**, 131.)

STANFORD. Water supply.—(Bull. **13**, 131.)

STAUNTON". Water supply.—(Bull. **10**, 174; **13**, 132.)
Proposed sewerage and sewage disposal.—(Bull. **12**, 134.)

STEGER, Water supply.—(Bull. **12**, 134.)

STEELING. Water supply .—(Bull. **11**, 127; **13**, 132.)

STOCKTON. Water supply.—(Bull. **11**, 12 7.)
Sewerage.—(Bull. **11**, 128.)

STONINGTON. Water supply.—(Bull. **11**, 128.)

STEAWN. Water supply.—(Bull. **11**, 130; **13**, 134.)
Typhoid fever.—(Bull. **11**, 130.)

STBEATOR. Water supply.—(Bull. **9**, 31; **11**, 128; **13**, 134.)
Pollution of Vermilion Eiver.—(Bull. **13**, 134.)

STRONGHURST. Proposed water supply.—(Bull. **12**, 135.)

SULLIVAN (2,621). Water supply.—(Bull. **11**, 130; **13**, 134.) Visited August 4 and October 11 and 12. A public water supply is now obtained from three wells but the yield is inadequate. The city has contracted for eight wells to yield a minimum of 200,000 gallons a day. Two wells, 12 inches in diameter, located about 350 feet apart, had been drilled on October 11. One is 284 feet deep and is cased to soft sandstone which is entered at a depth of 183 feet. The other well is 270 feet deep and is cased to the sandstone, which is entered at a depth of 177 feet. The stratum of sandstone extends to the bottoms of the wells. A pump pit and pump house have been built at the deeper well and pumping equipment has been installed. Before pumping the water level was at a depth of 93 feet. One well was pumped at a rate of 33 gallons a minute for more than 9 hours and the water level in the other well was lowered about 6 feet. On the following day the well was pumped about 6½ hours and it is not probable that the water level was drawn down to the pump cylinder, which was placed at a depth of 245 feet, as the pump discharge was constant. After the test water could be heard pouring in from the sides of the well showing that the water level had been lowered considerably. More extended tests should be made.

The water is of good sanitary quality. It has a mineral centent of 1080, a hardness of 256, and a content of iron of 6.5 parts per million.

SULLIVAN, Masonic Home. Proposed, improved water supply.—Conferences were held with a member of the Board of managers of the Illinois Masonic Home on July 29 and August 30 and the Home at Sullivan was visited on August 4 to study proposed improvements in the water supply. The Home has a resident population of about 170. It is located on a tract of over 400 acres of land about two miles east of the city of Sullivan.

Water is obtained from two wells five feet in diameter and about 43 feet deep, lined with brick and laid without cement except in the upper portions. Water is derived from very fine sand. At the top of one well is a pump pit with concrete floor in which there is a manhole opening. The opening does not have a water-tight cover. This well is equipped with a steam-head pump. The other well is equipped with an electrically operated pump. Water rises to within about 30 feet of the surface, but either well can be emptied by continuous pumping. Water is pumped directly into the distribution system to which a 40,000-gallon elevated steel tank is connected.

The daily consumption is estimated at about 10,000 gallons. The yield of the present wells is not adequate to meet the demands at all times.

The quality of the water is not satisfactory. The wells are subject to contamination by surface and shallow ground-water drainage passing through the walls. One well is subject to contamination by drainage from a pit at the top of the well, and there is a possibility of contamination from a sewer which passes within about 20 feet of one of the wells.

Sinking a new and deeper well, either near the present wells or near Jonathan Creek about one mile to the east, has been considered. In the city of Sullivan a fairly coarse bed of sand and gravel is encountered between depths of 70 and 90 feet and a 10-inch well in this formation has yielded from 25,000 to 40,000 gallons a day, an amount which would be entirely adequate for the Home except for fire protection. Several other wells in the city about 300 feet deep in sandstone yield possibly from 25,000 to 40,000 gallons a day. It was recommended that the city sink a tubular well, reeord the formation encountered, and test quality and quantity of water from each water-bearing stratum. Securing a supply from the drift would probably be advisable if a sufficient quantity could be secured, as the water from the wells in drift in the city is of better quality than the water derived from sandstone.

SULLIVAN. Proposed sewerage.—(Bull. **13**, 135.)

SUMMIT (949). Water supply.—Visited November 28. Summit is a manufacturing community in Cook County on the banks of the Chicago Sanitary and Ship Canal about 12 miles southwest of the center of Chicago.

Waterworks were installed about 1902. The source of supply is a well, 1,864 feet deep, 16 inches in diameter at the top and 8 inches in diameter at the bottom. A well 1,550 feet deep is to be cleaned out and placed in service. The well is equipped with an air lift. Air is furnished by an electrically driven air compressor. Water is discharged into a 78,000-gallon concrete reservoir. An electrically driven 4-inch centrifugal pump draws water from the reservoir and forces it into the distribution system. A 60,000-gallon elevated steel tank with top of tank 125 feet above foundations is connected to the distribution system. A 10-inch main extends from the station to the tank and to the street. All other pipes are 6 inches in diameter.

There are 152 consumers in Summit besides 248 consumers in a part of the village known as Argo. The total daily consumption is about 250,000 gallons of which 150,000 gallons is used by one industrial plant.

The water is of good sanitary quality. It has a mineral content of 708, a hardness of 304, and a content of iron of 0.5 parts per million.

SYCAMORE. Water supply.—(Bull. **11**, 131.)

TAMPICO (849). Water supply.—Visited December 28. Tampico is in the southeastern part of Whiteside County on the drainage area of Rock Biver. There is no sewer system in the village.

Waterworks were installed in 1912. Water is obtained from 3 wells 4 inches in diameter and 25 feet deep in sand and gravel. The wells are 10 feet apart on the corners of a triangle. Water is drawn from the wells and discharged into the distribution system by a 288,000-gallon horizontal duplex pump driven by a 12-horsepower gasoline engine. There are about 1.9 miles of 4-inch, 6-inch, and 8-inch pipe in the distribution system. A 40,000-gallon elevated steel tank is connected with the system. The top of the tank is at a height of 105 feet. There are 57 service connections. The waterworks cost about $13,200.

The water has a mineral content of 330, a hardness of 254, and a content of iron of 0.2 parts per million.

TAYLORVILLE. Water supply.—(Bull. **11**, 132.)

THOMSON (487). Water supply.—Visited October 12. Thomson is in the southwestern part of Carroll County on low flat land about 3 miles from the Mississippi Biver. The surface soil is underlaid by a deep bed of fine sand. Water is struck at a depth of from 20 to 22 feet.

Waterworks were installed in 1903 and few important changes have been made since that time. It is proposed to install new wells to save time and pumping, and also to replace the elevated tank with a larger tank. The source of supply is a 3-inch well 37 feet deep. The top of the well is in a pit. Water is pumped from the well into the distribution system by a pump driven by an oil engine. The distribution system includes 1,200 feet of 6-inch and 2,400 feet of 4-inch pipe, 13 hydrants, and 6 valves. There are water mains in all of the principal streets of the village. A 20,000-gallon elevated wooden tank on a 70-foot steel tower is connected to the distribution system. It was recommended that more wells be installed, that it would be advisable not to have pits which may be partly filled with contaminated water surrounding the tops of wells, and that the present tower should not be used for a larger elevated tank.

The water is of good sanitary quality.

TINLEY PARK. Water supply.—(Bull. **12**, 136.)

TISKILWA. Water supply.—(Bull. **9**, 31; **10**, 175.)

TOLEDO. Proposed water supply.—(Bull. **13**, 135.)

TOLONO. Water supply.—(Bull. **12**, 139.)

TOLUCA. Water supply.—(Bull. **11**, 132.)

TOULON. Water supply.—(Bull. **11**, 133.)

Sewage-treatment plant.—(Bull. **12**, 140.)

TREMONT. Water supply.—(Bull. **12**, 140.)

TRENTON. Water supply.—(Bull. **12**, 140.)

TROY (1,447). Proposed water supply.—Visited September 20 at the request of the Troy Commercial Club. Troy is in the southern part of Madison County about 18 miles northeast of E. St. Louis. There is a coal mine and a small glove factory in the city.

In 1914 the city drilled a well to a depth of 60 feet and then abandoned it. The possibility of securing water for a city supply from wells has not been thoroughly investigated. The population at present draws its water supply from private wells, the majority of which are from 20 to 35 feet deep. There are a few drilled wells, one to a depth of 105 feet. There are 2 shafts at the coal mine 285 feet deep. These drain into a sump from which water is pumped every day. Information concerning the amount of water pumped from the mine each day, whether or not the flow from water-bearing strata is sealed from the mine, and all other available data as to ground-water flow should be collected. The possibility of securing an impounded surface-water supply was investigated. It is probable that such a supply could be developed at a reasonable cost.

Methods of raising money to finance a water supply were discussed with members of the Commercial Club. It was recommended that the city council be advised of the interest of citizens in securing a public water supply and that the city employ an engineer to investigate possible sources of supply and to prepare an estimate of cost for a water system. The city should then vote on issuing bonds or allow its citizens to take subscriptions and raise funds with which to build waterworks.

TUSCOLA. Proposed improved water supply.—(Bull. **12**, 141; **13**, 136.)

UTICA. Water supply.—(Bull. **11**, 134.)

VILLA GROVE. Proposed water supply.—(Bull. **12**, 142; **13**, 137.)

VIRDEN. (4,000). Proposed water supply.—(Bull. **11**, 135.) Virden was visited on August 18 and 21 to assist in the test of a well proposed as a source of public water supply. The consulting engineers recommended the development of a supply from wells east of the city. After sinking fifteen small test wells in order to locate the best water-bearing stratum a 47½-foot well was drilled about one mile east of the city. It is 8 inches in diameter to a depth of 43¼ feet, below which it is 3 inches in diameter. It is cased to a depth of 16 feet, where soft sandstone is entered. The bottom of the well is in hard limestone. On August 21 after three days pumping, with the water level drawn down to 42½ feet below the surface, the yield was only 7.8 gallons a minute.

Water from the well had a mineral content of 262, a hardness of 176, and a content of iron of 3.2 parts per million.

WALNUT (763). Water supply.—Visited October 21. Walnut is in the northern part of Bureau County on the drainage area of Green River. There are no public sewers in the village.

Waterworks were installed about 1901. A well was drilled on high ground in the northern part of town and equipped with a gasoline-engine driven deep-well pump which discharged into a steel pressure tank connected to the distribution system. An elevated tank has been erected and the use of the pressure tank has been discontinued. Two additional wells have been drilled, one of which has been abandoned on account of trouble caused by fine sand entering the well. The two wells in use are each 6 inches in diameter and

230 feet deep in drift and have screens 20 feet long in the bottom. They are equipped with deep-well pumps which discharge directly into the distribution system. The two wells yield about 50 gallons a minute. Power is furnished by a 32-horsepower gasoline engine. A 6-inch water main extends from the pumping station through the business district of the village. All other pipe is of smaller size. An 80,000-gallon elevated wooden tank on a steel tower is connected with the distribution system. A pressure of about 35 pounds at the station and 50 pounds in the business district is maintained. More than one-half the residents use water from the public supply. The daily consumption is estimated at about 14,000 gallons.

The water is of good sanitary quality. It has a mineral content of 339, a hardness of 290, and a content of iron of 5 parts per million.

WARREN. Water supply.—(Bull. **11**, 136.)

WARSAW. Water supply.—(Bull. **10**, 176; **11**, 136; **13**, 137.)

Sewerage.—(Bull. **10**, 177.)

WASHINGTON" (1,530). Water supply.—Visited December 14. Washington is in the northeastern part of Tazewell County about 10 miles east of Illinois River. Part of the city is served by sewers which discharge into a creek which has no other flow during part of the year.

Bonds for the public water supply were voted in 1887. Water is obtained from two wells about 300 feet apart in glacial drift. One is dug to a depth of 60 feet below which it is drilled 8 inches in diameter to a depth of 90 feet. The other well is drilled 6 inches in diameter to a depth of 80 or 90 feet. The wells are equipped with electrically-driven deep-well pumps which dis. charge into the distribution system. The 8-inch well is generally used and its equipment includes an automatic starting device. A 15-horsepower gasoline engine furnished power to pump the 6-inch well in case of emergency. The original distribution system was of wooden pipe. All but 12 blocks have been replaced with cast-iron pipe. The wooden pipe remaining will withstand a pressure of about 50 pounds. An elevated steel tank on a 60-foot brick tower is connected to the distribution system.

The water is of good sanitary quality. It has a mineral content of 352, a hardness of 251, and a content of iron of 2.4 parts per million.

WASHINGTON. Disposal of canning-factory wastes.—(Bull. **11**, 339-73.)

WATERLOO (2,091). Water supply.—(Bull. **10**, 178.) Waterloo was visited August 17. The public water supply was augmented in 1914 by the addition of a second storage reservoir located in a small ravine just above the first reservoir. It covers about four acres. Surface drainage from a highway formerly entered the reservoirs but has since been diverted. Since acquiring this additional storage no water has been pumped from Fountain Creek. In 1915 the State Water Survey recommended that the reservoir be treated with copper sulfate in order to remove a troublesome growth of algae. This recommendation was carried out and since that time algae growths have not been bothersome.

WATERLOO. Microscopical and sanitary survey of reservoir.—Visited November 4. The water supply is derived chiefly from springs emerging from limestone rock and is added to by surface drainage from an area of about one-half a square mile. Water is impounded in a 40,000,000-gallon reservoir located two miles southwest of Waterloo. It covers an area of approximately 12 acres. Schorr Lake is also used as a storage reservoir. It covers about

4 acres. The water is subject to pollution from a roadway, from a house and barn located close to the reservoir, and from fishermen and picnickers. Micro-organisms were found to the extent of about 300 per cc. Filamentous micro-organisms were present in large enough quantities to give the water a bad physical appearance. Treatment with copper sulfate was not recommended at the time of the visit due to the near approach of winter which would kill off the undesirable organisms. On the whole the reservoir was in bad condition both from the microscopic and sanitary standpoint. It was recommended that a purification plant be installed to protect the health of the community.

WATERMAN (398). Water supply.—Visited March 28. Waterman is in the southern part of DeKalb County on a small tributary of Somonauk River.

Waterworks were installed in 1906. Previous to that time a few families had secured water from a private company. The supply is obtained from a well 6 inches in diameter and 72 feet deep, ending in gravel. Water is pumped from the well into the distribution system by a deep-well pump with its cylinder placed about 30 feet below the top of the well. The pump has a daily capacity of about 87,000 gallons and is belt-connected to a 12-horsepower gasoline engine. Operation by electric power is being considered. The distribution system includes 0.8 miles of 4-inch and 6-inch cast-iron pipe, some mains of smaller sizes, 14-fire hydrants, and 80 service connections. Meters are in general use. A 30,000-gallon elevated steel tank is connected to the distribution system. About one-half the population uses water from the public supply. The daily consumption is estimated at about 9,000 gallons.

The water is of good sanitary quality. It has a mineral content of 371, a hardness of 360, and a content of iron of one part per million.

WATSEKA, Iroquois County poor farm. Sewage disposal.—(Bull. **12**, 143.)

WAUKEGAN. Water supply.—(Bull. **9**, 31; **11**, 137; **13**, 139.)

WELDON (521). Water supply.—Visited December 12. Weldon is in the southeastern part of DeWitt County on the drainage area of Sangamon River. Private wells from 20 to 65 feet deep extending through rocky clay soil to gravel are used by all residents of the village. There are no public sewers,

Waterworks were installed in 1897. About 4 years later the well now in use was dug and the pumping station moved to its present location. The waterworks and a privately owned electric light plant were sold to the village in 1904 for $3,500. Since that time about 1,300 feet of 1¼-inch and 2-inch water pipe have been laid.

Water is obtained from a well which is 10 feet in diameter to a depth of 42 feet. In the bottom of the dug part 3 wells have been drilled to various depths. One reaching a depth of 86 feet is thought to be the principal source of supply at present. The dug part of the well is brick lined and the drilled wells are cased with iron pipe which extend 3 or 4 feet above the bottom of the dug well. When not pumping water stands about 23 feet below the surface and is drawn down about 11 feet by pumping. The well has a flat board cover which is not water-tight and is about level with the surrounding ground. Water is drawn from the well and discharged into the distribution system by a 7-inch by 6-inch by 8-inch horizontal duplex steam pump located in a pit about 12 feet deep. There are about 1,400 feet of 4-inch mains and 6,500 feet of smaller mains in the distribution system. Wrought-iron and galvanized-iron pipe are used. The 4-ineh main extends from the station through the business district to a 17,000-gallon elevated wooden tank on a 51-foot iron-pipe tower. This tank was built at the time the waterworks were installed in 1897. It was recommended that the supply be better protected from contamination, that water of a better quality be secured if possible, and that larger mains be used to furnish fire protection.

The water is not used for drinking purposes and should not be unless the source of supply is better protected from contamination. It has a mineral content of 632, a hardness of 488, and a content of iron of 1.5 parts per million.

WENONA (1,442). Water supply.—(Bull. **13**, 139.) Visited December 14 to investigate waste and consumption of water in the village.

The source of supply is a deep well which is equipped with a steam-head deepvwell pump. The depth to the water level in the well when not pumping was reported to be 125 feet on March 29, 1915 and 152 feet on December 19, 1916. By increasing the rate of pumping it is possible to draw the water down to the pump cylinder 260 feet below the surface. A pump cylinder had been dropped into the well and another old cylinder that was on hand was in use at the time of the visit. The pump was said to have a capacity of 180,000 gallons but after having run continuously for several months it pumped less than one-third of this amount. The pump discharges into a surface reservoir from which water is pumped into the distribution system by a pressure pump. All water passes through a meter in the pumping station. The Wenona Light and Power Co. operates the station in connection with an electric light plant and is paid 8 cents per 1,000 gallons for pumping water.

Water is supplied to the village of East Wenona. In the two villages there are about 4.2 miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. At the time of visiting Wenona there were 267 services of which 173 were metered. There were 37 services in East Wenona, all of which were metered. From May 1, 1915, to November 31, 1916 the monthly pumpage varied from 966,000 gallons to 2,000,000 gallons.

Meter readings of water used by the Wenona Coal Co. for three-month periods were available and it was assumed that the electric light plant used about 2,000 gallons a day. There are no other large consumers. All other records of meter readings were destroyed by fire so that water waste could not be determined directly. Assuming a daily leakage of 10,000 gallons, the average number of services in use is 300, and allowing for water used by the Wenona Coal Co. and the Wenona Light and Power Co. the average domestic consumption from June 1, 1915, to November 1, 1916, was 112 gallons per service. This is practically the same as it is in many cities where the supply is metered and gives no evidence of great waste. It may be, however, that the amount used and wasted was limited by the capacity of the pump.

The determination of the discharge of the pumps and of the accuracy of the meter in the pumping station by checking with the measured amount added or taken from the surface reservoir was recommended. The drilling of another well was recommended.

WENONA. Proposed sewage.—(Bull. **13**, 139.)

WEST BROOKLYN (266). Water supply.—Visited March 30. West

Brooklyn is in the southwest part of Lee County on the drainage area of Greene River, a tributary of Rock River.

Waterworks were installed in 1897. The supply was obtained from a well 385 feet deep terminating in water-bearing gravel. On account of sand entering this well it was abandoned in 1913, and water has since been purchased from an elevator company, which has a 3-inch well 375 feet deep. A new village well to be 385 feet deep had been drilled to a depth of 327 feet at the time of the visit. It has 8-inch casing to a depth of 290 feet, below which it is to be 6 inches in diameter to the bottom. Fine sand was encountered at a depth of 280 feet. The new well will be equipped with a double-acting deep-well pump, driven by a 15-horsepower electric motor. The distribution system includes about 1700 feet of 4-inch and 6-ineh mains, 6 fire hydrants, and 55 service connections. A steel pressure tank 8 feet in diameter and 36 feet long is connected to the distribution system. The pressure varies from 60 pounds to 40 pounds. The daily consumption is estimated at 12,000 gallons.

The water from the well now in use is of good sanitary quality. It has a mineral content of 375 and a hardness of 333 parts per million.

WEST CHICAGO. Water supply.—(Bull. **12**, 143.)

WEST DUNDEE. Water supply.—(Bull. **9**, 32.)

WEST FRANKFORT (2,111). Proposed water supply.—(Bull. **11**, 137; **12**, 144.) Visited February 10, April 9 and 10, and April 25 and 26. An engineer has been employed and the contract awarded for drilling and equipping two wells to be used as a source of public supply. The wells are guaranteed to yield at least 300,000 gallons a day. After drilling 25 small test holes the two wells were located north of the city in the bottom lands of Middle Fork of Big Muddy Creek. One well has been drilled 24 inches in diameter and 62 feet deep and has been provided with an 18-inch casing and an 18-inch shutter screen 20 feet in length. The well penetrates 35 feet of clay, 8 feet of mixed sand and clay and 19 feet of fine sand. The other well has not been completed. The first well was pumped for four hours and forty minutes at a rate of about 200 gallons a minute and the water level was drawn down to 47 feet 8 inches below the surface. Two days after pumping the water had risen to 9 feet 2 inches below the surface. Pumping 20 hours at the rate of about 164 gallons a minute the water level was lowered to 52 feet 9 inches below the surface.

The water is of good sanitary quality but is highly mineralized. It has a mineral content of 1234, a hardness of 636, and a content of iron of .17 parts per million.

WEST HAMMOND. Water supply.—(Bull. **12**, 144.)

WESTERN SPRINGS. Water supply.—(Bull. **13**, 140.)

WESTVILLE (2,607). Proposed water supply.—(Bull. **13**, 140.) Visited July 24, to inspect test wells and to confer with city officials regarding the proposed water supply.

Information obtained from mine operators indicated that there was a thicker vein of water-bearing sand and gravel about two miles east of the city than could be found in other near by localities. Three 6-inch wells have been sunk in this vicinity. One well, 102 feet in depth, penetrated a water-bearing stratum between depths of 60 and 76 feet, and entered shale at 80 feet. Another well, 117 feet in depth, penetrated water-bearing sand

and gravel between depths of 81 and 83 feet. The yield of these two wells was very small. The other well is 212 feet deep. A. water-bearing stratum was penetrated between depths of 64 and 70 feet. Below this depth the well penetrated clay to a depth of 100 feet, below which it passed through shale and coal. After drawing the water down to a depth of 70 feet, the inflow into the well was 2.9 gallons a minute.

Insanitary conditions prevail in the city and there is evident need for a public water supply. Test wells could be of small diameter and need be sunk only through the drift and not continued through rock, as has been done. The advisability of using water from a mine is being considered. This mine water has a mineral content of 3042 and a hardness of 594 parts per million. It would not be a very satisfactory water supply.

WHEATON. Sewage purification.—(Bull. **10**, 180.)

WHITEHALL. Incrustation of mains and filtration of water supply.—(Bull. **11**, 138; **13**, 142.)

Sewerage.—(Bull. **11**, 139.)

WILMETTE. Water supply and sewerage.—(Bull. **9**, 31.)

WINCHESTER (1,639). Water supply.—(Bull. **11**, 139; **12**, 145.) Visited August 2. Winchester is in the central part of" Scott County in the drainage basin of Illinois Eiver. Waterworks were completed in October 1914. Water is obtained from two wells located about 100 feet apart on the Grout farm south of town. Each well is 8 inches in diameter, 42 feet deep and contains 29 feet of 8-ineh casing and a 13-foot Johnson strainer. The bed of sand and gravel from which the water is obtained is about 13 feet thick. A test of the wells at the time of drilling showed a yield from each of 72,000 gallons a day. This quantity will easily supply the demands that may be placed on the wells for several years in the future. Each well is equipped with a 72,000-gallon electrically driven deep-well pump, which forces the water into the distribution system. This comprises 0.5 mile of 2-inch wrought-iron and 5.5-miles of 4-inch, 6-inch, and 8-inch cast-iron pipe. There are 110 service connections, all of which are metered. An 80,000-gallon elevated steel tank is connected to the distribution system. The average daily consumption is estimated at 27,000 gallons. The water works cost $29,000.

The water is of good sanitary quality. It has a mineral content of 323, a total hardness of 285, and a content of iron of 0.4 parts per million.

WINNETKA. Water supply.—(Bull. **11**, 140; **13**, 143.)

WITT. Proposed water supply.—(Bull. **10**, 184; **11**, 140.)

WOOD EIVER (84). Water supply.—Visited September 21. Wood River is in the western part of Madison County about one mile from the Mississippi River and 20 miles north of East St. Louis. It adjoins the grounds of a large refinery of the Standard Oil Co. The city is growing rapidly and the present population is estimated at 2,000. It has a combined system of sewers discharging into Mississippi River.

Waterworks were installed in 1912. The distribution system was built by the city and is being extended from time to time. Water is sold to the city by the Standard. Oil Co. at a rate of 5 cents per 1,000 gallons. The water is obtained by the company from 9 wells 16 inches in diameter and from 110 to 140 feet deep in water-bearing sand and gravel. The installation of more wells is contemplated. Each well is equipped with a motor-driven centrifugal pump. The yield of each well is estimated at 1,000,000 gallons a day. Water stands about 26 feet below the surface when not pumping and is lowered to a depth of 40 feet during pumping.

The water is of good sanitary quality. It has a mineral content of 320, a hardness of 264, and a content of iron of 0.4 parts per million.

WOODHULL (692). Water supply.—Visited October 9. Woodhull is in the southwestern part of Henry County. There are no sewers in the village.

Waterworks were installed in 1902. The source of supply is a well 1294 feet deep, 12 inches in diameter at the top and decreasing to 6 inches in diameter at the bottom. The static water level is at a depth of 200 feet. The well is equipped with an electrically-driven deep-well pump with its cylinder at a depth of 267 feet. The pump discharges into a 94,000-gallon concrete reservoir. Water is pumped from this reservoir into the distribution system" by an electrically-driven 7-inch by 10-inch triplex pump. A 35-horsepower gas engine furnishes power in case of emergency. The distribution system includes 1.8 miles of 4-inch, 6-inch, and 8-inch mains, 30 hydrants, and 198 service connections. A 68,000-gallon elevated wooden tank on a 75-foot steel tower is connected with the distribution system. Nearly all residents use water from the public supply. Services put in during the past year are metered.

The water is of good sanitary quality. It has a mineral content of 929, a hardness of 168, and a content of iron of 0.6 parts per million.

WOODSTOCK. Water supply.—(Bull. **9**, 32; **12**, 145.)

WYOMING. Water supply.—(Bull. **12**, 146.)

YORKVILLE. Water supply.—(Bull. **9**, 32.)

Proposed sewerage.—(Bull. **11**, 141.)

ZION CITY. Water supply and sewage conditions.—(Bull. **9**, 32.)

THE ACTIVATED-SLUDGE METHOD OF SEWAGE TREATMENT*

By F. W. Mohlman.

INTRODUCTION

The Nuisance Removal Act, passed by the British Parliament in 1855, at the close of a severe cholera epidemic, marks the beginning of the scientific study of the chemistry and biology of sewage. This was the first appreciation of the necessity for treating sewage in such a manner as to render it nonputrescible.

Since 1855 innumerable theories have been advanced, and many processes have been tried but the ideal process has not yet been found. Plants which were among the first constructed, and plants representing all processes having any merit at all are still in use.

Disposal by dilution in streams was the earliest method and is still in most general use in the United States. In 1915,[19] 83 per cent of the 41,800,000 people in the United States who were connected with sewerage systems discharged raw sewage into water. courses, lakes, or the ocean.

Broad irrigation is one of the older methods, and is still in use at the sewage farms of Paris and Berlin. The immense amount of land required has prevented extensive adoption of this practice.

Chemical precipitation has been used extensively. The sewage is treated with lime, lime and iron, alum, or a combination of these chemicals and the precipitate formed is allowed to settle. Although this process is still in use, it is limited because of the large amounts of comparatively worthless sludge produced, and because of the necessity of further treatment in order to obtain complete purification of the sewage.

When septic tanks were invented it was thought that the most satisfactory solution of the sewage-disposal problem had been found. The septic tank is still in general use in the United States but the early claims that all organic matter would be destroyed have not been substantiated. Some of the solid organic matter applied in the sewage is liquified and gasified but at times sludge is discharged with the effluent. The tanks require occasional cleaning, the sludge has little value as a fertilizer, and the odor from such tanks is

*A thesis submitted in partial fulfillment of the requirements for the degree of doctor of philosophy, June, 1916. The investigation was carried out under the direction of Professor Edward Bartow.

usually very bad. Purification by this process is not complete, and if it is used in conjunction with further treatment, and septic action is carried too far, complete purification of the sewage is retarded.

Until recently the septic tank has been considered the most satisfactory preliminary treatment, but it has been gradually supplanted in new installations by the Imhoff tank. The special advantage which the Imhoff tank has over the septic tank is its two-story construction by which the settling solids and the gases of fermentation are separated from the incoming sewage. This tank is open to the same objection, however, as the septic tank for it also produces a large amount of valueless sludge.

Some means of oxidation is necessary for the final treatment of sewage. The intermittent sand filter was the first type to be used successfully in America, and under certain conditions is still a very satisfactory method of treatment. The great objection to the sand filter is the excessive amount of land required and the expense of construction when sand of the proper quality is not procurable. These objections practically eliminate the sand filter from installations for large cities. Although the capacity can be increased by preliminary treatment of the sewage, there is also an increased production of worthless sludge.

The contact filter has fallen into disuse because of the variable degree of purification effected, and because frequent cleaning and careful attention are required. Preliminary treatment is necessary with contact filters.

The sprinkling filter is widely used at the present day, and yet it has several disadvantages. Its construction requires a great deal of land and immense quantities of crushed stone. The effluent is of variable quality and contains considerable suspended matter, which must be removed in secondary settling basins. Odors are sometimes very pronounced and a justifiable objection is the presence at certain seasons of myriads of flies, gnats and bugs. The production of sludge is unavoidable.

Imhoff tanks for preliminary treatment and sprinkling filters for final treatment are usually recommended for present-day installations. In all the methods mentioned the disposal of the sludge is a great problem. Because of the small amount of fertilizing elements it contains it is practically worthless, and often entails considerable expense for its disposal. The situation is comparable to that which exists in gold mining, where millions of dollars worth of gold are present in tailings from which the metal cannot be recovered profitably. Millions of dollars worth of nitrogen and phosphorus are present in sewage, only awaiting some process by which they may be recovered profitably. With the propaganda of conservation of our resources being pushed so actively at the present time, this by-product of our modern civilization should not be overlooked. Any process that will recover these elements profitably must surely be ranked as one of the greatest discoveries of the century. The process of treating sewage by aeration in the presence of activated sludge promises in certain cases to recover this nitrogen and phosphorus profitably and to compete, from the standpoint of purification, with any of the present methods.

HISTORICAL REVIEW

The earliest attempts to oxidize sewage by aeration were made by Dupre and Dibdin[9] on the sewage of London and by Dr. Drown[7] on the sewage of Lawrence, Massachusetts. They found that oxidation accomplished in this way was a very slow process, and accordingly not at all practicable.

In 1892 Mason[18] and Hine conducted experiments on the oxidation of sewage by means of aeration. They concluded that air had but little oxidizing effect on sewage.

In 1894 Waring[20] attempted to apply air on a working scale at Newport, R. I., but his project was unsuccessful.

In 1897 Fowler[10] aerated the effluent from the chemical precipitation tanks at Manchester, England, but without accomplishing any considerable degree of purification. In 1911 aeration was again attempted. Black and Phelps[6] studied the possibility of aerating the sewage of New York City. They aerated sewage in tanks filled with inclined wooden gratings for varying periods up to twenty-four hours. The oxidation was so slight that determinations of nitrogen showed practically no purification, although some measure of improvement was indicated by the incubation tests. Black and Phelps recommended the process for a large-scale installation but it was not adopted.

Clark, Gage, and Adams[7,8] had tried aeration of sewage, at the Lawrence Experiment Station, but had been unable to obtain satisfactory results until 1912. In that year, however, they were able to nitrify sewage successfully by aeration for twenty-four hours in a tank containing vertical slabs of slate placed about one inch apart, and covered with a zoogleal mass of colloidal matter deposited from the sewage. They submitted the effluent to further treatment for they did not claim that the aeration would entirely obviate filtration.

Gilbert J. Fowler[10] of Manchester, England, had tried aeration with some modifications on English sewages, but had obtained only indifferent results. Upon his return to England after a visit to Lawrence in 1912, he suggested work on aeration to Edward Ardern and W. T. Lockett, resident chemist and assistant chemist, respectively, at the Davyhulme Sewage Works of Manchester. On April 3, 1914, they reported[2] the remarkable results which they had obtained in their preliminary investigations.

In their first experiment, Ardern and Lockett aerated samples of Manchester sewage in gallon bottles, until complete nitrification was accomplished; the aeration was affected by drawing air through the sewage with an ordinary filter pump.

Aeration for about five weeks was required to obtain complete nitrification. The clear oxidized liquid was then removed by decantation, raw sewage added to the deposited sludge, and aeration continued until the sewage was again completely nitrified. This procedure was repeated a number of times. The amount of deposited solids increased, and the time required for complete nitrification decreased until eventually raw sewage was completely nitrified in six to nine hours.

The sludge, which induced such active nitrification was called "activated sludge" by Ardern and Lockett.

In August, 1914, Edward Bartow[5] saw the work in progress at Manchester, and upon his return to this country, suggested that experiments with activated sludge be started at the University of Illinois.

EXPERIMENTAL WORK

EXPERIMENTS IN BOTTLES

In the first series of experiments, sewage, collected as needed from the main outfall sewer of Champaign, was aerated in three-gallon bottles. The sewage was strong and fresh and contained no industrial wastes.

Aeration of sewage without sludge. A gallon of sewage, collected at 9 a. m. on November 2, 1914, was aerated until completely nitrified. An unmeasured amount of compressed air from the University supply was blown into the sewage through glass tubes. This process repeated with different samples of sewage when no activated sludge was present showed the course of the purification (see Table 1 and Figure 1). The ammonia nitrogen decreased, at first gradually, then more rapidly as the aeration continued. The nitrite nitrogen increased in proportion to the decrease of ammonia nitrogen. After the nitrite nitrogen

TABLE 1.—AERATION OF SEWAGE IN 3-GALLON GLASS BOTTLES WITH NO ACTIVATED SLUDGE PRESENT. AIR DISTRIBUTION THROUGH GLASS TUBE.

Date.	Time [Days.]	Nitrogen. [Parts per million.] Ammonia.	Albuminoid.	Nitrite.	Nitrate.
Dec. 18	0	38.00	5.20	.07	.37
Dec. 19	1	30.00	4.20	.02	.38
Dec. 21	3	28.80	4.00	.11	.45
Dec. 28	10	22.00	3.60	5.00	.20
Dec. 29	11	8.00	2.60	16.00	.40
Dec. 30	12	1.60	2.40	23.00	1.00
Dec. 31	13	.36	1.88	28.00	2.00
Jan. 1	14	.16	1.48	31.00	1.00
Jan. 2	15	.....	.....	33.00	.....
Jan. 4	17	.....	.....	33.00	.....
Jan. 5	18	.....	.....	30.00	.....
Jan. 6	19	.28	1.92	27.00	5.00
Jan. 7	20	.44	1.84	14.00	18.00
Jan. 8	21	.28	1.68	.30	31.70
Jan. 9	22	.24	1.60	.05	31.95

had reached a maximum and the ammonia nitrogen was practically all oxidized, there was a relatively sudden change of nitrite into nitrate nitrogen. The complete aeration of sewage in four different experiments gave concordant results.

Aeration of sewage with activated sludge. Activated sludge was built up in the manner suggested by Ardern and Lockett.[20] Sewage was aerated to complete nitrification, the supernatant liquid decanted

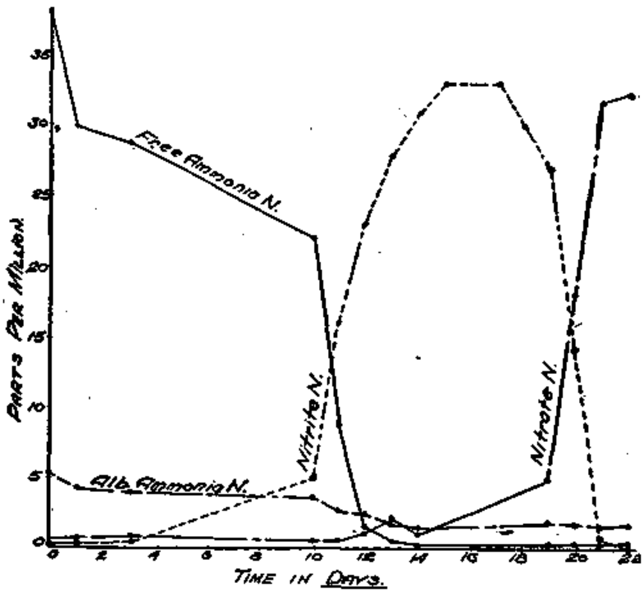


Figure 1.—Aeration of sewage in 3-gallon glass bottles with no activated sludge present. Air distribution through glass tube.

after the suspended matter had settled. This process was repeated and sludge accumulated. The time required for nitrification decreased very rapidly and on the seventh treatment nitrification was complete in *12½* hours. On the thirtieth treatment, with about 33 per cent of sludge, the time required for complete nitrification was between four and five hours.

The course of the reaction was very different from that when no activated sludge was present (see Table 2 and Figure 2). The ammonia nitrogen decreased rapidly, nitrate nitrogen increased as ammonia nitrogen decreased, and nitrite nitrogen never reached a high amount as in the previous experiment (see Table 3).

TABLE 2.—AERATION OF SEWAGE IN 3-GALLON GLASS BOTTLES IN PRESENCE OF ACTIVATED SLUDGE (1 SLUDGE: 3 SEWAGE). AIR DISTRIBUTION THROUGH GLASS TUBE.

Date.	Time. [*Hours.*]	Nitrogen. [*Parts per million.*] Ammonia.	Nitrite.	Nitrate.
Feb. 6	0	22.00	1.80	2.80
Feb. 6	2	9.00	6.00	10.40
Feb. 6	4	.18	4.00	16.80
Feb. 6	6	.20	.10	23.90
Feb. 6	8	.18	.10	23.90

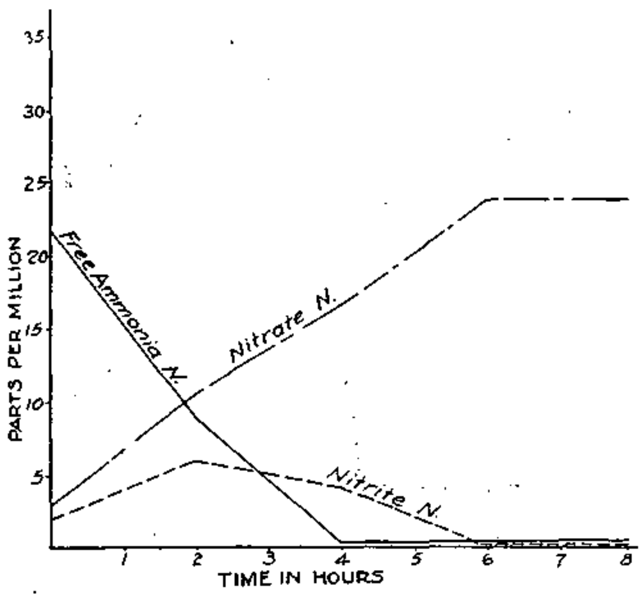


Figure 2.—Aeration of sewage in 3-gallon glass bottles in presence of activated" sludge (1 sludge: 3 sewage). Air distribution through glass tube.

TABLE 3.—FORMATION OF NITRITE NITROGEN CAUSED BY AERATION OF SEWAGE IN PRESENCE OF ACTIVATED SLUDGE.

[Parts per million]

Date.	Series A.		Series B.	
	Aeration [*Hours.*]	Nitrite Nitrogen.	Aeration [*Hours.*]	Nitrite Nitrogen.
Jan. 9	0	.18		
	2	.01		
	4	.00		
	6	.20		
	8	.43		
	9	1.25		
	10	3.00		
	11	.40		
	13	.10		
Jan. 11	0	.00	0	.00
	1	.00	1	.00
	2	.00	2	.00
	3	.01	3	.10
	5	.02	5	4.00
	6	.02	6	4.50
	7	.10	7	6.50
	12	.05	12	.30
	24	.00	24	.15
Jan. 16	0	.30	0	.30
	1	.55	1	.00
	2	1.60	2	.30
	3	3.60	3	1.65
	5	6.60	5	3.60
	1 hour settling		1 hour settling	
	5	6.40	5	3.20
	6	6.00	6	3.40
	6	7.60	6	3.60
	7	8.40	7	3.60
	9	8.60	9	8.00
	24	.15	24	.20
Jan. 18	0	.00	0	.00
	1	.00	1	.00
	3	.10	3	.05
	4	.40	4	.15
	6	1.00	6	.25
	1 hour settling		1 hour settling	
	8	1.50	8	.25
	9	2.40	9	.20
	10	1.70	10	.15
	11	.70	11	.10
	20	.05	20	.05
Jan. 20	0	.00	0	.00
	9	3.80	9	8.00
	10	4.00	10	7.40
	11	4.50	11	7.60
	12	3.90	12	5.40
	13	.10	13	.20
	14	.10	14	.10

The reactions with and without activated sludge differ greatly as may be seen in Tables 1 and 2 and Figures 1 and 2. The nitrification in both experiments follows the nitrogen cycle, that is, nitrogenous organic matter is oxidized to ammonia nitrogen then to nitrite and finally to nitrate nitrogen. In aeration of sewage without sludge the last two stages are quite distinct, but in the presence of activated sludge, the formation of nitrite nitrogen is immediately followed by oxidation to nitrate nitrogen. In other words, the speed of the reaction

Nitrite + 0 = Nitrate

is nearly equal to that of

Ammonia + 0 = Nitrite

Since the oxidation is biological, this would seem to show the presence of great numbers of nitrite- and nitrate-forming bacteria in the activated sludge. These forms have been isolated from the sludge by Russel.[21]

These experiments led to the following theory of the action of activated sludge.

The oxidation of the organic matter of sewage is accomplished by biological agencies since both air and bacteria are essential. The bacteria must be of the proper type, that is, nitrifying forms. The reaction is:

Ammonia nitrogen + Nitrifying bacteria + Air = Nitrate nitrogen.

In the aeration of sewage without sludge, the nitrifying forms are very few in number, because conditions are usually unfavorable for their presence and growth in sewage as it flows through sewers. At times, during hot weather, the sewage is entirely anaerobic, which means practically the elimination of all nitrifiers. With the few nitrifying bacteria present, the complete nitrification of sewage without sludge must take place slowly.

With the accumulation of activated sludge, and by the maintenance of continuous aerobic conditions in the aerating tanks there are optimum conditions for the growth of nitrifying bacteria. These bacteria increase enormously, and the time necessary for complete nitrification is greatly shortened.

The above theory may account for the accelerated nitrification but other features of the process, such as the clarification and reduction in bacteria are probably caused by other agencies.

The clarifying efficiency of the activated-sludge process is remarkable. Most of the effluents contain very little colloidal matter. The removal of colloidal matter must undoubtedly be caused by the absorptive power of the spongy, flocculent sludge acting in conjunction with the "scrubbing" effect of the air. The sludge may also remove the bacteria in about the same manner as a chemically precipitated floe. Russel[21] has shown that an average of 95 per cent of the bacteria are removed in 4-hours' aeration in the presence of 25 per cent of sludge.

T. Chalkley Hatton,[15] who has conducted extensive experiments with activated sludge at Milwaukee, reports that 97 per cent of bacteria are removed in 3½ hours' aeration in the presence of 25 per cent of sludge.

To prove whether or not the action of enzymes assists in clarification and bacterial removal, 25 per cent of clarified effluent was added to raw sewage. No clarification resulted other than that caused by the dilution. It is not likely that enzymes are of much assistance in clarification.

EXPERIMENTS IN LABORATORY TANK

The experiments just described yielded accurate data concerning certain chemical and biological features of the process, but it was realized that the volume of sewage treated was small, the air distribution poor, and the volume of air undetermined. In order to treat larger volumes of sewage, to get a better distribution of air, and to measure the air, a new apparatus was built.

Description of apparatus. A tall wooden box, 9 inches square and 5 feet deep, was fitted with a plate-glass front and back to permit easy observance of the air distribution and the condition of the sewage and sludge (see Figure 3). A porous plate IV2 inches thick and 9 inches square, of a patented material called "Filtros" was cemented

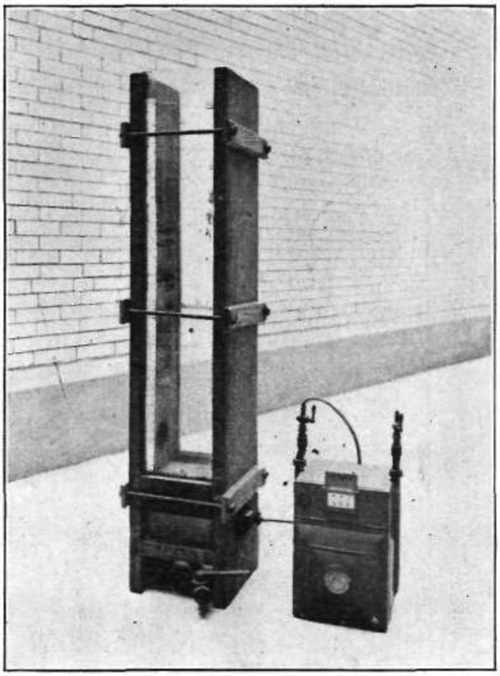


Figure 3.

four inches above the bottom of the tank. "Filtros" is manufactured by the General Filtration Co. of Rochester, New York. It is made of carefully graded quartz sand mixed with ground glass; when heated the glass fuses and binds the mixture firmly together. Air passes through the plate freely and in fine bubbles.

An inlet for air and an outlet for water which might filter through the plate, opened into the space below the plate. Compressed air from the University supply was measured through an ordinary gas meter. A siphon was used to remove the supernatant liquid after the sludge had settled. Experiments were carried on at room temperature.

Accumulation of sludge. The diffusion of the air through the plate reduced the time required for complete nitrification of the first sewage treated to 15 days (see Table 4 and Figure 4). The air re-

TABLE 4.—AERATION OF SEWAGE IN LABORATORY TANK WITH NO ACTIVATED SLUDGE PRESENT. UNIFORM DISTRIBUTION OF AIR THROUGH POROUS PLATE.

Date.	Time. [*Days.*]	Nitrogen. [*Parts per million.*] Ammonia	Albuminoid	Nitrite	Nitrate
Jan. 4	0	36.00	6.60	.01	.70
Jan. 7	3	34.00	3.40	1.20	.60
Jan. 11	7	0.40	3.00	32.00	2.00
Jan. 18	14	0.60	2.60	7.50	18.50
Jan. 19	15	0.80	2.20	.10	25.90

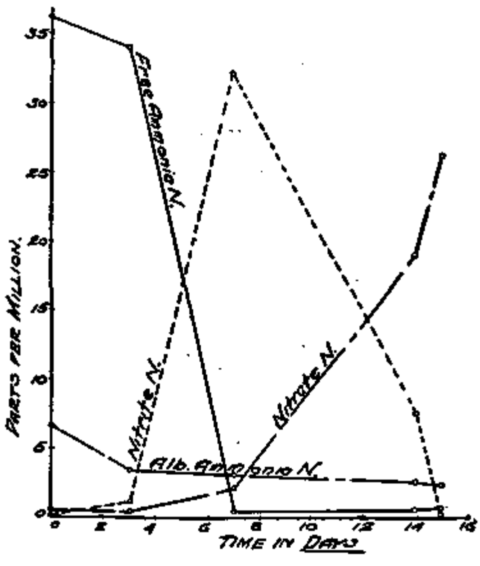


Figure 4.—Aeration of sewage in laboratory tank with no activated **sludge** present. Uniform distribution of air through porous plate.

quired for the 16 gallons of sewage in the tank amounted to 4,830 cubic feet. The raw sewage contained 36 parts per million of ammonia nitrogen and 0.7 part per million of nitrate nitrogen. The effluent contained 25.9 parts per million of nitrate nitrogen and 0.8 part per million of ammonia nitrogen.

In the second treatment, the time required for complete nitrification was but four days, with a reduction of the air to 1,270 cubic feet. The raw sewage contained 34 parts per million of ammonia nitrogen and practically no nitrate nitrogen. The effluent contained 23.8 parts per million of nitrate nitrogen and practically no ammonia nitrogen.

In the third treatment nitrification was complete in two days with the use of 720 cubic feet of air. The raw sewage contained 33 parts per million of ammonia nitrogen, the effluent contained 22.3 parts per million of nitrate nitrogen.

In the twelfth treatment, nitrification was complete in less than eight hours with the use of less than 128 cubic feet of air.

In the thirty-first treatment with sludge and sewage in the proportion of 1:5, nitrification was complete in less than five hours; 35 cubic feet of air were used, equal to 0.20 cubic foot per square foot of surface area per minute or about 3 cubic feet per gallon of sewage. The effluent after one hour's aeration did not decolorize methylene blue in twelve days. The raw sewage contained 27 parts per million of ammonia nitrogen. The effluent contained 22.1 parts per million of nitrate nitrogen (see Table 5 and Figure 5).

The results obtained in this short period of aeration were excellent, but it was learned from later operation that such results could not be obtained consistently unless aeration was continued until all of the ammonia nitrogen was removed. The quality of the effluent depends upon the condition of the sludge which in turn depends upon the extent to which previous aerations have been carried. By aerating until

TABLE 5.—AERATION OF SEWAGE IN LABORATORY TANK IN THE PRESENCE OF ACTIVATED SLUDGE (1 SLUDGE: 5 SEWAGE). UNIFORM DISTRIBUTION OF AIR THROUGH POROUS PLATE.

Date.	Time. [*Hours.*]	Nitrogen. [*Parts per million.*] Ammonia	Nitrite.	Nitrate.
Feb. 24	0	27.00	.05	.59
	1	13.00	2.40	6.00
	2	8.20	2.80	10.80
	3	3.70	3.40	15.00
	4	.20	2.60	10.60
	5	.20	0.30	22.10

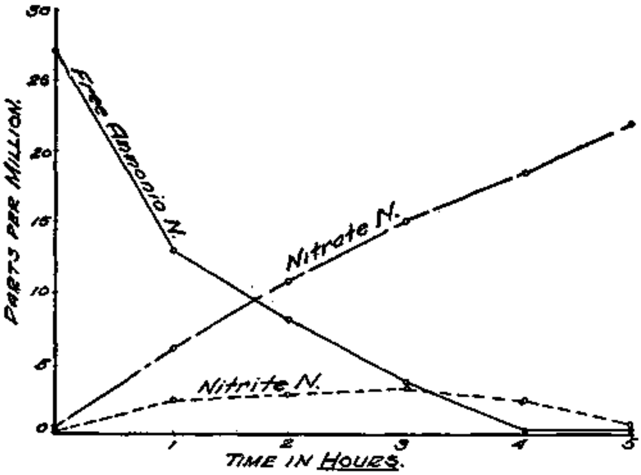


Figure 5.—Aeration of sewage in laboratory tank in the presence of activated sludge (1 sludge : 5 sewage). Uniform distribution of air through porous plate.

ammonia nitrogen has disappeared, the sludge becomes more effective for further use.

In accumulating sludge in the laboratory tank, the periods of aeration varied. The sewage was not changed at night and many sewages were aerated for a long time after the ammonia nitrogen had disappeared.

AVith this method of operation, very excellent results were obtained in a short period of aeration, but such results could not be maintained, unless the sewage were overtreated occasionally. If the ammonia nitrogen is not completely oxidized there is but slight formation of nitrite and nitrate nitrogen, the amounts becoming smaller in each succeeding effluent. When once the sludge becomes inactive it requires considerable aeration to re-activate it.

Owing to the impossibility of controlling the temperature of the room at night, high temperatures occasionally prevailed, which may have caused the sludge to lose its activity. When the sludge was in this inactive condition, it would not settle, but appeared very colloidal, and sometimes had a slightly septic odor. If it were aerated for a long time with occasional addition of fresh sewage, however, it would again become normal.

Quantity of sludge. When the sludge had increased to about 33 per cent of the total volume of the tank it was removed to a depth of 6 inches above the plate and dried. Eight portions of sludge were removed, the amount of water present was determined, and the weight of dry sludge per million gallons of sewage calculated. The results of these determinations are given in Table 6.

TABLE 6.—QUANTITY OF SLUDGE OBTAINED FROM AERATION OF SEWAGE IN LABORATORY TANK.

Date.	Grams wet	Grams dry	Per cent water.	Gallons of sewage.	Kgms. of dry sludge per million gal. sewage.
Mar. 15	4,400	75	98.3	...	....
Mar. 18	4,400	57	98.7	...	....
Mar. 23	9,400	132	98.6	...	....
Mar. 31	14,400	185	98.7	135	1,400
Apr. 8	9,750	121	98.8	196	620
Apr. 15	7,400	154	97.9	214	720
Apr. 30	8,300	185	97.8	360	515

Average per cent water in sludge 98.4.

There were wide variations in the amount of sludge formed per unit of sewage. When sludge was removed frequently, the amount formed appeared greater than when it was allowed to remain in the tank for a longer period. For example, in 3 days, from March 23 to March 26, 2550 kilograms per million gallons, in 5 days, from March 26 to March 31, 1,400 kilograms per million gallons, and in 8 days, from March 31 to April 8, only 620 kilograms of sludge per million gallons of sewage were formed.

Sludge was probably liquefied by overtreatment. This theory was verified by dividing a portion of sludge into two parts, drying one portion immediately, and aerating the other for 24 hours with 4 volumes of purified effluent before drying. The loss amounted to 1.1 grams, or approximately 5 per cent.

Weight of sample dried immediately	23.7	grams
Weight of sample dried after 24 hours' aeration	22.6	grams
Loss by over-aeration	1.1	grams

The large amount of sludge obtained may have been caused by the fact that the sewage used was collected at 9 a. m. when the Champaign city sewage at the point of collection was strongest and contained the maximum amount of suspended matter, probably 2 to 3 times the average. If the suspended matter were completely removed from a sewage containing 300 parts per million of suspended matter, 1,120 kilograms of dry sludge would be obtained per million gallons of sewage. Sewage containing 135 to 365 parts per million of suspended matter, assuming 100 per cent retention of suspended matter in the activated sludge, would give the amount of the dry sludge obtained.

Analyses of the sludge were made by W. D. Hatfield[4], as a part of a thesis on the fertilizer value of activated sludge. The sludge was found to contain from 3.5 to 6.4 per cent of nitrogen.

A phenomenon was noted in connection with the operation of the tank which was thought at the time to be of importance. Small red worms were present in the sludge in such numbers that in places the sludge had a red appearance. The species was identified by Professor Frank Smith, of the University of Illinois, as Aeolosoma hemprichii,' an annelid worm about 2 to 5 millimeters long and rather slender. It is found in water containing an abundance of decaying organic matter, and thrives especially well where there is much fermentation, as in a water contaminated with sewage but provided with an abundant supply of oxygen. It belongs to a group of worms in which reproduction occurs very rapidly by asexual methods. It feeds almost continuously on any small organic particles that it can obtain, and presumably consumes at least its own weight of organic matter every clay.

Because of the facts noted above, it was thought that this worm was an important agency in the purification of the sewage. However, it was proved by Robbins Russel[21] that the worms were not essential, and that their presence was merely accidental and of no consequence. They were not found at any time in the larger-scale experiments reported later, and have not been found at other places except at Washington, D.C, where they were found in activated sludge obtained during the course of laboratory experiments.

Their presence in the tank in the laboratory, and absence in the, large tanks may have been caused by a number of factors; the laboratory experiments were conducted in a light room in a tank with glass sides, the temperature in the laboratory was higher, and the aeration was often continued until large amounts of nitrate nitrogen were formed. The worms disappeared at times when effluents were putrescible. Possibly nitrate is necessary for their growth and existence.

Effect on fish life. Considering that sustenance of fish life would be an excellent indication of the good quality of the effluent, some small fish obtained from the Salt Fork Creek near St. Joseph on April 17, 1915, were placed in a 20-liter jar which was filled with effluent from the tank. The liquid was aerated continuously and changed each time the effluent was removed from the tank.

The fish seemed to thrive at first, but in three days two of the smallest died. In seven days another died, and in ten days, shortly after the addition of a putrescible effluent, all of them died.

This test was inconclusive, as the degree of purification was variable during the period of observation. When' the effluent was nonputrcscible the fish seemed to suffer little discomfort, and had all of the effluents been stable, it is probable that the fish would have lived. It was proved, at least, that a nonputrescible effluent from the activated-sludge process, if aerated, is not immediately toxic to fish.

EXPERIMENTS IN CONCRETE TANK

The work with the laboratory tank was continued until April 30, 1915. On May 6, 1915, experiments on a larger scale were begun, using four concrete tanks built in the basement of the University power plant (see Figures 6 and 7). This location was chosen because it was the most convenient place that could be found for tapping the main sewer of the city of Champaign. The conditions under which the experiments were conducted were similar to those which would be obtained by housing a plant.

Description of tanks. Each tank is 3 feet 2 inches square, thus having an area of 10 square feet. Each tank is 8 feet 5 inches deep above Filtros plates 1½ inches thick, which are used for diffusing the air. These plates were considered to be the most satisfactory air-diffusing medium available.

In tanks A and B there are 9 plates, each 12 inches square, covering the entire floor.

In tank C there are three plates, covering three-tenths the area of the floor. They form a central trough to which the concrete sides slope at an angle of 45 degrees.

In tank D there is but one plate, covering one-tenth the area, of the floor. The four concrete sides slope to the plate at an angle of 45 degrees.

The plates are set on steel T-bars 4 inches above the bottom of the tank. The space below is drained by a 2-inch pipe, and when a tank is being drained air pressure is released under the.plates by a petcock attached to a one-inch pipe. If the pressure is not released, bubbles of air pass through the plates and stir up the sludge and supernatant liquid.

The air, obtained from the University compressed-air plant at a pressure of 80 pounds per square inch, is reduced by a pressure-reducing valve to 8 pounds per square inch. The quantity of air supplied is further regulated by a hand-operated valve before it passes through meters on each tank. These meters are the ordinary gas meters which were tested by the local gas company during the course

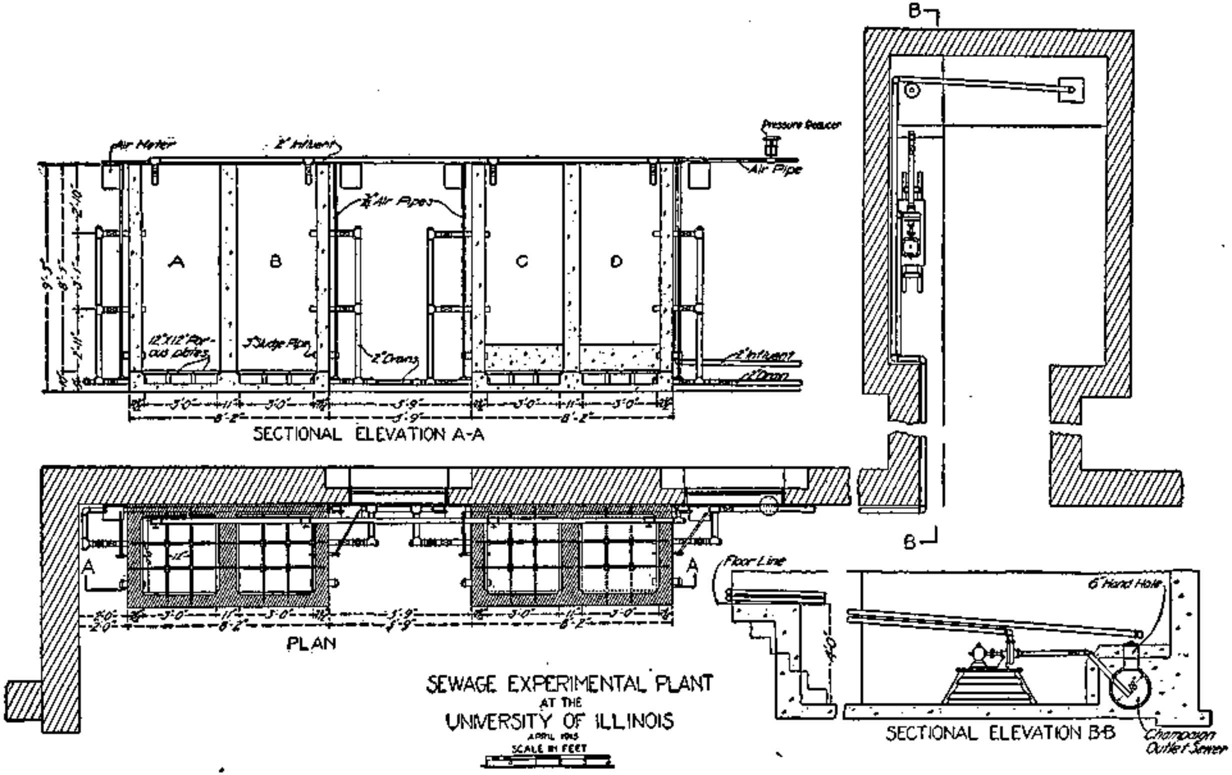


Figure 6.—Plan and elevation of concrete tanks.

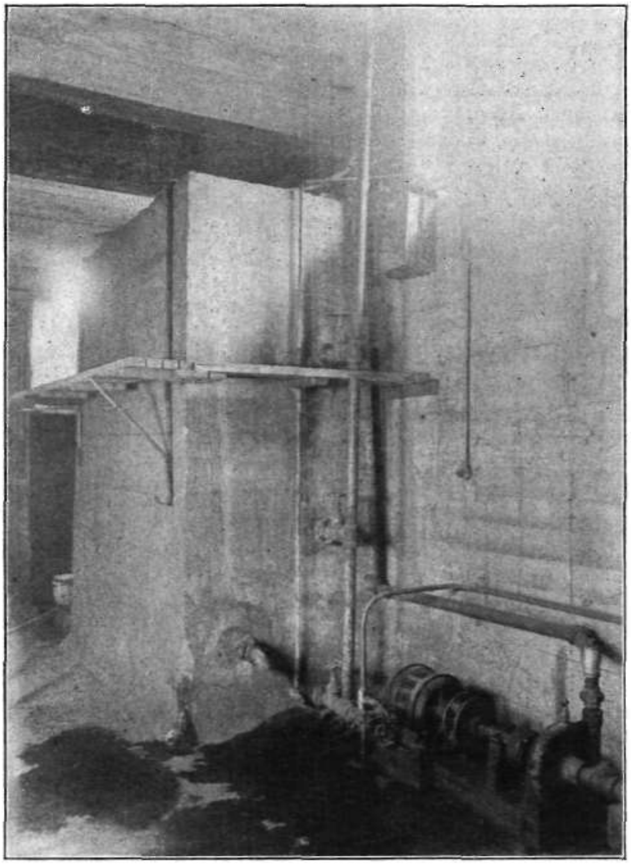


Figure 7.

of the experiments, and were found to register with a fair degree of accuracy. The pressure under which the air enters the tank is but little more than that necessary to balance the hydrostatic pressure of the sewage and the friction of the plates. It is equivalent to 8 inches of mercury, or a little less than 4 pounds per square inch. The friction in passing through the plates amounts to but a fraction of a pound pressure.

Two outlets for the effluent are, respectively, 2 feet 6 inches, and 5 feet 7 inches above the plates. Changes were made in these outlets for the later experiments.

Raw sewage was pumped as needed by a 2-inch centrifugal pump direct-connected to a 2-horsepower 3-phase motor. This pump will fill one tank in 6 minutes. Each tank can be drained to the lower outlet in 8 minutes.

A 3-inch sludge pipe with a quick-opening valve was introduced into each tank 5 inches above the plates, for removing sludge when necessary. This design was faulty as the pipe should have entered the tank just above the plates in order that all of the sludge might be removed.

Plan of operation. The operation of the four tanks was so planned that special features might be studied by varying (1) the strength of sewage treated, (2) the amount of air used, (3) the quantity of sludge present, (4) the length, of the period of aeration, and (5) the amount of air-diffusing area. The quantity of sewage treated per filling was approximately constant, the amount varying only slightly according to the amount of sludge present. Approximately 400 gallons were added at each filling.

Accumulation of sludge. The time required for the accumulation of the requisite quantity of activated sludge is of great importance from a practical standpoint. In the original experiments of Ardern and Lockett[2] and in our first experiments the sewage was aerated until all ammonia nitrogen had been oxidized. Under these conditions nearly two months are required for the accumulation of sufficient activated sludge to operate a plant. In the meantime but a very small portion of the sewage can be treated. In order to shorten this long period of preparation, sludge was accumulated by removing the effluent before the ammonia nitrogen was entirely oxidized to nitrate nitrogen. In this way some degree of purification was obtained as soon as operation began and sludge was accumulated more rapidly. The rapid method of accumulating sludge was studied by comparative operation of two tanks. Tanks A and B were put in operation on

TABLE 7.—ACCUMULATION OF SLUDGE DURING AERATION OF SEWAGE IN TANK A. AERATION CONTINUED FOR 11 DAYS.

Date.	Period of Aeration [*Hours.*]	Amount of Air. [*Cu. ft.*]	Nitrogen. [*Parts per million.*] Ammonia.	Nitrite.	Nitrate.	Total Organic.	Oxygen-Consuming Capacity.	Stability [*Per cent.*]
May 5	0	0	28.0	....	...	21.6	88.0	...
6	18.5	3,600	16.0	.35	.95	10.4	21.2	...
7	42.5	.....	15.0	.35	.....	5.3	22.0	...
8	72.	9,430	12.0	.45	.75	5.0	22.8	...
9	98.	12,480	18.0	.45	.85	4.2	20.8	...
10	121.	15,400	17.0	.50	1.00	4.0	20.4	90
11	144.	18,220	14.0	1.5	.10	3.6	20.4	96
12	167.	21,440	14.0	2.0	.10	4.2	22.8	100
13	192.	25,340	15.0	3.3	.10	5.2	24.0	100
14	218.	29,100	13.0	4.7	.20	4.8	25.2	100
15	238.	32,080	10.0	12.5	.50	5.6	32.8	100
16	270.	35,930	0.4	26.0	1.0	6.2	35.0	100

May 5, 1915. The sewage in tank A was aerated without interruption for eleven days until all ammonia nitrogen was oxidized (see Table 7), that in tank B was changed every 24 hours during the same period (see Table 8).

TABLE 8.—ACCUMULATION OF SLUDGE DURING AERATION OF SEWAGE IN TANK B. SEWAGE CHANGED EVERY 24 HOURS DURING 11 DAYS' AERATION.

Date	Sewage	Amount of Air. [Cu. ft.]	Period of Aeration. [Hours.]	Nitrogen. [Parts per million.] Ammonia.	Nitrite.	Nitrate.	Total Organic.	Oxygen Consuming Capacity.	Stability [Per cent.]
May 5	Raw	2830	24	28.0	....	....	21.6	88.0	...
5	Eff.	....	..	16.0	.35	.95	10.4	21.6	...
6	Raw	2430	23	19.0	....	....	19.3	60.0	...
6	Eff.	....	..	15.0	.45	.95	9.9	22.4	37
7	Raw	3840	23	24.0	....	....	12.0	42.0	...
7	Eff.	....	..	15.0	.50	1.4	6.2	22.4	75
8	Raw	2660	25	16.0	....	....	9.6	29.0	...
8	Eff.	....	..	11.0	.4	1.8	5.4	12.0	84
9	Raw	2200	22	21.0	....	....	15.2	47.0	...
9	Eff.	....	..	16.0	.5	2.3	5.3	14.4	84
10	Raw	1650	21	20.0	....	....	11.5	46.0	...
10	Eff.	....	..	12.0	1.0	1.0	4.2	15.2	90
11	Raw	3990	22	18.0	....	....	15.0	75.0	...
11	Eff.	....	..	8.0	1.7	1.0	5.0	21.2	90
12	Raw	1750	24	19.0	....	....	16.7	83.0	...
12	Eff.	....	..	10.0	1.6	.5	4.6	19.2	96
13	Raw	2450	24	18.0	....	....	12.2	52.0	...
13	Eff.	....	..	11.0	3.6	.4	5.4	23.6	97
14	Raw	1530	19	27.0	....	....	15.4	64.0	...
14	Eff.	....	..	18.0	5.0	.5	5.0	25.2	100
15	Raw	3900	31	23.0	....	....	12.5	70.0	...
15	Eff.	....	..	5.0	15.0	1.0	6.5	50.0	100
16	Raw	1420	16	26.0	....	....	32.6	171.0	...
16	Eff.	....	..	4.0	20.0	2.0	5.4	48.00	100

Thus, during the 11 days, 12 times as much sewage was treated in B as in A. After one hour's settling in Imhoff cones, there was one per cent of sludge by volume in A, and 10 per cent in B. On May 16, after 11 days' aeration, the effluent from tank B was clearer than that from tank A.

After 11 days' continuous aeration of the sewage in tank A, using 35,930 cubic feet of air, ammonia nitrogen had been reduced from 28 to 0.4 parts per million, nitrite nitrogen increased to 26 parts per million, nitrate nitrogen to 1.0 part per million. Oxygen consumed was reduced from 88 to 35 parts per million, total organic nitrogen from 21.6 to 6.2 parts per million, and the supernatant liquid had a stability of 100 per cent.

After 11 days' aeration of the sewage and sludge in tank B, using 1,420 cubic feet of air, ammonia nitrogen was reduced from 26.0 to 4.0 parts per million, nitrite nitrogen increased to 20 parts per million, and nitrate nitrogen to 2.0 parts per million. Oxygen consumed was reduced from 171 to 48 parts per million, total organic nitrogen from

32.6 to 5.4 parts per million, and the effluent had a stability of 100 per cent.

The results obtained by changing the sewage in tank B every day were so much better than those obtained by continuous aeration of the sewage in tank A that this experiment in tank A was discontinued.

The operation of tank B was continued changing the sewage every 24 hours, until after 15 days, ammonia nitrogen in the effluent was less than 1.0 part per million. Then the sewage was changed every 12 hours and after 8 days ammonia nitrogen in the effluent was less than 1.0 part per million. Then the sewage was changed every 6 hours and after 4 days ammonia nitrogen in the effluent was again less than 1.0 part per million. The sewage was well nitrified by this sludge, and the sludge had the same appearance and properties as that accumulated by complete nitrification of each quantity of sewage added.

This comparison indicated that it was not necessary to aerate until all ammonia nitrogen was removed from the sewage, in order to obtain a satisfactory sludge.

After this activated sludge was accumulated in tank A by changing the sewage after 12 hours' aeration. The data correspond to those obtained during the operation of tank B on the 24-hour schedule. Stable effluents were obtained in 7 days; complete removal of ammonia nitrogen was accomplished in 18 days, after which the sewage was changed after 6 hours' aeration. The effluents obtained from tank A during this 6-hour cycle were in general as good as those obtained from tank B, in which sludge had been accumulated by changing the sewage once a day.

In a later experiment in tank C, sludge was accumulated by changing the sewage after 6 hours' aeration. Stable effluents were obtained in 15 days; removal of ammonia nitrogen to less than one part per million occurred in 20 days. The sludge accumulated in this way had the same characteristics as sludge accumulated by changing the sewage only when all the ammonia nitrogen was removed, and was apparently just as highly "activated."

The conclusion was reached that activated sludge can be accumulated by aerating each addition of sewage for six hours. It has been thought that the accumulation of sludge would be long, tedious process, and in order to shorten this process slurry from sprinkling filters,[2] Imhoff sludge,[22] and other kinds of sludge have been proposed as "starters." Our work showed that sufficient sludge could be obtained from Champaign sewage in a week, by aerating each addition of sewage for 6 hours, that no starter need be used, and that a considerable degree of purification could be obtained from the beginning of operation.

Operation of tanks A and B. Tanks A and B were operated continuously from May 21 until November 1. During this time 400 gallons of sewage were applied at each filling. Effluents were removed and sewage added 4 times a day, except in a few instances when the influent pipe was plugged up by rags or the motor refused to work. Such accidents account for most of the periods of overaeration. The amount of air applied and the time of aeration were variable. The amount of sludge remained approximately constant after 25 per cent had been obtained. Only once was sludge removed from either tank. On June 30 the sludge in tank A was well stirred, and 6 inches were removed and dried on a sand bed; the sludge was further dried on a steam bath, to a final weight of 485 grams. On July 9, 6 inches were removed from tank B; the dried sludge weighed 1,660 grams.

It was somewhat surprising to find that even though sludge was not removed, only 30 per cent had accumulated in tanks A and B. The failure to accumulate sludge may have been because it was drawn off with the effluent, or because it was digested and liquified in the tank as fast as formed. Sludge is liquified by overaeration, (see page 87) such as prevailed at times during this experiment with tanks A and B. Warm weather may have accelerated the digestion. Owing to the failure to accumulate sludge no data concerning the amount of sludge formed were obtained. Special determinations concerning this were made later with tank C (see pages 100-103).

Analyses of the raw sewage and effluents from tank A from May 21 to November 1, were averaged by weeks (see Table 9). Similar data were obtained from the experiments in tank B but they are omitted since they are practically identical with those for tank A.

During the first period, from May 21-24, with very little sludge, effluents were not stable even with 12 hours' aeration and 2.0 cubic feet of air per gallon of sewage.

From May 25-31, effluents were approximately 90 per cent stable with 11 hours' aeration using 1.5 cubic feet of air per gallon of sewage. From June 1-7 effluents were of about the same quality with 11 hours' aeration using 1.5 cubic feet of air per gallon of sewage.

During the period of June 8-14, the time of aeration was reduced to 5 hours, and the air to less than one cubic foot per gallon. The effluents from the weak 3 a. m. sewage were stable, but those from the 9 a. m., 3 p. m., and 9 p. m. sewages were unsatisfactory. We have considered that a stability under 70 per cent indicates a poor effluent.

From June 15-21, with about 0.8 cubic foot of air per gallon, all effluents from 3 a. m. sewages were stable; those from 9 a. m. sewages were good, but the effluents from the 3 p. m. and 9 p. m. sewages were quite poor.

From June 22-28, the results were the same as those for the previous week.

During the period, June 29 to July 5, with one cubic foot of air per gallon all effluents from the 3 a. m. sewages were stable, but even with 1.5 cubic feet the other effluents were very poor.

From July 6-12 more air was applied, the average being 2.5 cubic feet per gallon, and longer aeration was given, resulting in stable effluents from all sewages.

During the next week, from July 13-19, the air was again reduced to about 1.0 cubic foot per gallon, the period of aeration to 5 hours; effluents were unsatisfactory.

From July 20-26, with 1.0 cubic foot of air per gallon and 4.5 hours' aeration, all effluents except those from 3 a. m. sewage were poor.

From July 27 to August 2, with 0.9 cubic foot of air per gallon, and 4.5 hours' aeration, all effluents were stable, but the raw sewage was very weak because of excessive rainfall.

During the entire month of August nitrification was good and all effluents were excellent. During the first and last weeks, however, because of the excessive rainfall, the raw sewage was very weak.

Normal sewage was obtained from August 10-23 and during this period 1.3 cubic feet of air per gallon and 4.6 hours' aeration gave very stable effluents.

During the first week of September, with 6 hours' aeration and 1.3 cubic feet of air per gallon stable effluents were still being obtained from normal sewage.

From September 7-13, with 5 hours' aeration and 1.1 cubic feet of air per gallon all effluents, except that from the 3 *a.* m. sewage, were very unsatisfactory.

During the period September 14-20, with 5 hours' aeration and 1.0 cubic foot of air, effluents were fairly stable. The raw sewage, however, was weak during this period.

From September 21 to October 4, even with 1.9 cubic feet of air per gallon and 6.7 hours' aeration, all effluents were very poor.

In order to determine whether the quality of the effluents could be improved by aerating the sludge alone for a certain period, no sewage

TABLE 9.—RECORD OF THE OPERATION OF TANK A, MAY 21-NOVEMBER 1, 1915.

Date.	Time of Filling.	Period of Aeration.	Amount of Air.	Raw.	Effluent.			
				Nitrogen. [*Parts per million.*]				Stability
		[*Hours.*]	[*Cu. ft.*]	Ammonia.	Ammonia.	Nitrite.	Nitrate.	[*Per cent.*]
May 21–24	9–11 a. m.	12.7	800	37.8	26.5	.15	.5	24
25–31	9–11 a. m.	10.7	740	21.4	12.4	3.6	3.3	83
	10–11 p. m.	11.6	590	17.4	9.6	4.0	3.5	91
June 1–7	10–11 a. m.	11.0	600	22.7	5.6	2.8	4.5	91
	11 p. m.	11.0	510	18.7	6.2	2.1	5.8	80
8–14	3 a. m.	5.0	320	10.2	3.8	1.7	6.9	99
	9 a. m.	5.8	390	31.7	14.3	1.3	2.1	70
	3 p. m.	5.0	310	17.8	14.3	.1	.6	54
	9 p. m.	5.0	300	21.7	12.4	.6	.9	74
15–21	3 a. m.	5.0	270	11.8	6.6	1.9	4.2	100
	9 a. m.	5.0	320	28.3	16.7	.7	1.3	81
	3 p. m.	5.0	290	17.1	14.3	.5	.4	48
	9 p. m.	5.0	270	19.3	14.0	.6	.5	52
22–28	3 a. m.	5.1	310	12.9	7.0	3.1	3.2	100
	9 a. m.	5.1	390	29.7	17.7	.9	.8	67
	3 p. m.	4.7	300	17.3	13.2	.2	.3	53
	9 p. m.	5.0	330	20.7	12.5	.9	.4	70
June 29–July 5	3 a. m.	5.0	400	16.7	10.8	.5	1.8	100
	9 a. m.	4.9	520	32.3	22.2	.1	.0	17
	3 p. m.	6.6	930	24.5	16.2	.6	.2	68
	9 p. m.	5.0	380	22.0	16.3	.0	.4	45
July 6–12	3 a. m.	4.5	1170	4.7	.3	1.1	11.1	100
	9 a. m.	14.5	1700	24.3	12.3	4.7	4.6	78
	3 p. m.	4.0	530	15.1	6.9	3.6	3.8	74
	9 p. m.	6.1	540	12.6	6.2	3.3	4.0	82
13–19	3 a. m.	4.5	370	8.2	2.0	1.8	2.6	99
	9 a. m.	4.5	530	23.7	10.3	1.3	2.0	61
	3 p. m.	4.5	420	13.3	8.1	.1	.5	62
	9 p. m.	6.2	400	17.3	9.9	.7	1.0	77
20–26	3 a. m.	4.5	420	10.5	5.2	1.6	47.7	98
	9 a. m.	4.5	510	31.1	17.8	.8	1.1	68
	3 p. m.	4.5	440	17.4	13.9	.3	.6	56
	9 p. m.	4.5	350	18.8	11.3	.4	1.0	..
July 27–Aug. 2	3 a. m.	5.4	420	5.0	2.1	2.5	9.5	100
	9 a. m.	4.5	350	14.7	9.3	1.3	10.8	85
	3 p. m.	4.5	350	7.9	6.1	.7	6.7	80
	9 p. m.	4.5	350	8.7	4.3	1.5	8.7	75
Aug. 3–9	3 a. m.	4.5	320	4.3	.2	16.2		100
	9 a. m.	5.4	410	17.4	7.2	12.3		9
	3 p. m.	4.5	340	9.2	6.1	7.7		90
	9 p. m.	4.5	360	10.4	2.4	9.6		100
10–16	3 a. m.	4.5	350	5.9	.7	8.6		95
	9 a. m.	5.4	610	30.1	8.2	6.2		..
	3 p. m.	4.5	580	16.3	1.5	5.7		..
	9 p. m.	4.5	420	16.1	2.9	4.1		..
17–23	3 a. m.	4.5	490	6.8	.0	9.7		..
	9 a. m.	4.5	520	28.8	10.7	5.1		..
	3 p. m.	4.5	570	12.3	4.4	5.8		..
	9 p. m.	4.5	420	14.7	6.3	3.6		..
24–30	3 a. m.	4.5	380	3.4	.0	14.5		100
	9 a. m.	4.5	520	17.7	1.1	16.2		100
	3 p. m.	4.5	530	11.3	.7	10.4		100
	9 p. m.	4.5	400	10.8	.0	12.0		100

TABLE 9.—RECORD OF THE OPERATION OF TANK A, MAY 21-NOVEMBER 1, 1915. (Continued).

Date.	Time of Filling	Period of Aeration. [Hours.]	Amount of Air. [Cu. ft.]	Raw. Nitrogen. [Parts per million.] Ammonia.	Effluent. Nitrogen. [Parts per million.] Ammonia.	Effluent. Nitrite. Nitrate.	Stability [Per cent.]
Aug. 31–Sept. 6	3 a. m.	4.5	410	5.7	1.0	7.9	100
	9 a. m.	7.1	580	25.1	5.8	7.5	95
	3 p. m.	7.5	640	10.8	5.2	2.1	75
	9 p. m.	5.5	490	14.7	4.5	5.1	92
Sept. 7–13	3 a. m.	4.5	330	8.7	3.6	2.6	96
	9 a. m.	6.2	630	32.4	10.4	2.7	60
	3 p. m.	4.5	350	15.8	13.6	.0	28
	9 p. m.	4.5	320	17.1	12.6	.3	44
14–20	3 a. m.	6.2	410	3.9	2.6	2.6	90
	9 a. m.	4.5	430	21.8	12.9	.0	73
	3 p. m.	4.5	430	13.1	8.9	.1	80
	9 p. m	4.5	380	14.9	9.8	.8	63
21–27	3 a. m.	4.5	250	8.3	8.1	.3	60
	9 a. m.	8.8	1450	30.6	18.3	2.3	55
	3 p. m.	4.5	500	18.8	15.5	.3	22
	9 p. m.	4.5	360	20.9	15.9	.0	28
Sept. 28–Oct. 4	3 a. m.	17.0	1480	13.4	6.9	5.1	84
	9 a. m.	6.5	690	32.5	18.5	1.1	75
	3 p. m.	4.5	780	18.3	10.3	.0	30
	9 p. m.	4.7	580	22.1	12.2	1.3	51
SLUDGE ALONE AERATED FROM 3:30–8:00 a. m.							
Oct. 5–11	3 a. m.	9.6	1300	....	....	....	..
	9 a. m.	5.8	610	39.6	27.7	.1	23
	3 p. m.	4.3	600	21.1	16.2	.0	20
	9 p. m.	4.5	470	26.1	18.3	.0	16
12–18	3 a. m.	12.6	1800	....	....	....	..
	9 a. m.	4.6	650	41.6	28.0	1.0	38
	3 p. m.	4.9	630	21.5	19.4	.2	33
	9 p. m.	4.5	570	28.2	18.8	1.2	56
ALL SEWAGES AERATED.							
Oct. 19–25	6 a. m.	5.3	1110	8.8	6.9	5.1	100
	10 a. m.	5.4	850	40.0	25.4	1.5	76
	5 p. m.	5.7	670	21.6	18.1	.0	41
	12 p. m.	4.6	660	30.5	21.7	1.3	65
Oct. 26–Nov. 1	6 a. m.	4.4	1020	9.0	7.8	2.9	98
	10 a. m.	6.7	1530	38.2	20.8	2.1	78
	5 p. m.	4.7	900	19.2	13.4	.1	57
	12 p. m.	5.1	660	26.3	17.9	.2	55

was added at 3 a. m., and the sludge alone was aerated from 3:30 to 9 :00 a. m. This procedure was followed from October 5-18, but no satisfactory effluents were obtained.

From October 19 to November 1, sewage was added four times a day, but the time of addition was changed from the previous schedule. The weak sewage added at 5:30 a. m. was easily nitrified and that added at 9:30 a. m. gave a fairly stable effluent with an excessive amount of air and a long period of aeration. Sewages added at 4:30 p. m. and 11 p. m. gave poor effluents, however, with normal amounts of air and a normal period of aeration.

Amount of air-diffusing area necessary. A comparative test was made in tanks C and D, to determine the relative efficiency of the diffusion area in these tanks. The bottom of tank C contains 3 square feet of Filtros plates for each 10 square feet of floor area; the bottom of tank D contains but one square foot. The tanks were operated from July 6-19 (see Table 10) under similar conditions. In each tank the sewage was changed 47 times, an average of four times a day.

• The effluents from tank D were uniformly poorer than those from tank C. It is possible that the difference was caused by the fact that but 0.9 cubic foot of air per gallon was used with tank D, and 1.13 cubic feet per gallon was used with tank 0. It is more probable that the poor results in tank D were caused by the insufficient amount of distribution area. The amount of air supplied to the sewage in tank D was always sufficient to keep the sludge well mixed with the sewage, but not much more air could have been used without excessive agitation of the sewage and sludge. The best results have uniformly been obtained with tank C. Results obtained with tank D were very unsatisfactory.

TABLE 10.—COMPARISON OF THE RESULTS OBTAINED BY AERATION OF SEWAGE WITH PLATE SURFACE IN TANK C THREE-TENTHS OF THE FLOOR AREA AND IN TANK D ONE-TENTH OF THE FLOOR AREA.

Number of Fillings.	Period of Aeration.	Air for 400 gals. sewage.	Raw.	Effluent.			
				Nitrogen. [*Parts per million.*]			Stability.
	[*Hours.*]	[*Cu. ft.*]	Ammonia.	Ammonia.	Nitrite.	Nitrate.	[*Per cent.*]
Tank C. 47	4.9	454	14.6	10.8	.5	1.4	50
Tank D. 47	4.9	360	14.6	12.1	.1	.5	18

A diffusion area covering three-tenths the floor surface gives much better results than a diffusion area covering either all, or one-tenth, the floor surface (see Table 10). This ratio might possibly be reduced to one-sixth or one-seventh the floor area without marked deterioration in the quality of the effluent but no tests were made of such areas.

The Filtros plates were very satisfactory for air diffusion. They distributed the air in fine bubbles, and gave no trouble through clogging or breaking. In large installations plates of uniform porosity must be used and the manufacturers are attempting to produce a more uniform grade of plates for use in sewage aeration. The plates must be set as nearly as possible at the same level, as a variation of one-fourth inch will cause uneven air distribution.

QUANTITY OF SLUDGE FORMED

In order to avoid loss of sludge during the removal of the effluent, several short lengths of 2-inch pipe were loosely threaded together so that they would collapse and one end was connected to the lower outlets of tanks A, B, and C. During aeration the open end of these pipes was held above the surface of the sewage by means of a chain. After the sludge had settled, the open end could be lowered to within a few inches of the sludge, and effluent could be drawn off without disturbing the sludge.

In order more surely to prevent loss of sludge a hollow cast-iron frame one foot square and 6 inches wide was screwed onto the free end of the collapsible effluent pipe in tank C. The sides of this frame were covered with a 16-mesh copper screen, through which the effluent had to flow. After this device had been installed a few determinations of the amount of sludge obtained were made in tank C.

A determination of the actual weight of sludge formed in 12 days was made. Prior to July 20, 1915, tank C had been filled 47 times, each time with an average of 435 gallons, or making a total of 20,400 gallons. After draining the effluent, the sludge was removed and placed on a small sludge-drying bed, 4 by 8 feet in plan. The sides of the bed were constructed of 12 by 2-inch boards. Coarse sand was placed in this frame to a depth of 8 inches and cheese-cloth was spread over the sand in order to avoid mixing sand with the sludge. Because of rains the sludge dried very slowly so that it was finally necessary to dry it on a steam bath. After drying it weighed 10,610 grams which is equivalent to 520 kilograms to 1,150 pounds per million gallons of sewage.

Compared with later results this value is high, perhaps because of the addition of sand and gravel from the sludge-drying bed.

Sludge was removed from tank C on November 5. Part of it was placed on the sludge bed, and the remainder on another bed made of crushed coal which was also covered with cheese-cloth. This sludge never did dry, because of rain, snow, and cold weather, and the weight of the dry sludge was not obtained. The experiments with sludge-drying beds were considered very unsuccessful since it was shown that the success of such a method of drying is dependent largely on weather conditions.

Tank C was operated from January 6-25, 1916, changing the sewage usually four times a day. On January 25, after the effluent had been removed, the amount of sludge was calculated. The solids in an aliquot portion of this sludge were determined and the amount of dry sludge then calculated.

Fifty-four additions of sewage of 400 gallons each and three additions of 200 gallons each had been made. The data and calculations are given below.

Weight dry sludge.

Depth of sludge in tank C	30 inches
Quantity of sludge in tank C	22 cubic feet
Weight of sludge in tank C	1,386 pounds
Per cent of solids in sludge	1.17 per cent
Weight of dry sludge	16.2 pounds
Total volume of sewage added	22,200 gallons
Amount of dry sludge per million gallons (calculated)	750 pounds

Tank C was operated in a similar manner from March 9-23, 1916. The same calculations were made as in the previous case.

Weight dry sludge.

Depth of sludge in tank C	30 inches
Quantity of sludge in tank C	22 cubic feet
Weight of sludge in tank C	1,386 pounds
Per cent of solids in sludge	0.98 per cent
Weight of dry sludge	13.6 pounds
Total volume of sewage added	18,400 gallons
Amount of dry sludge per million gallons (calculated)	740 pounds

The limited data obtained from the three experiments just described indicated that from 740 to 1,150 pounds of dry sludge may be obtained per million gallons of Champaign sewage.

COMPOSITION OF SLUDGE

Content of nitrogen. If activated sludge is to be used as a fertilizer its most important constituent is nitrogen. Three series of determinations have been made of the increase in the content of nitrogen during the initial accumulation of activated sludge in tank C.

The first series of samples was collected from tank C during the period from October 4 to November 4. The sewage was changed three times a day for the first three weeks, with five hours' daily aeration of the sludge alone; after that four changes of sewage per day were made. An average of 800 cubic feet of air per gallon and 4.9 hours' aeration were used during each aeration period. The strength of the sewage treated was normal. Thirteen samples of sludge were taken at intervals, filtered on a Biichner funnel, dried on the steam bath, and the amount of nitrogen determined (see Table 11).

TABLE 11.—CONTENT OF NITROGEN IN SAMPLES OF SLUDGE COLLECTED FROM TANK C, OCTOBER 4 TO NOVEMBER 5, 1915.

Sample No.	Date.	Time. [*Days.*]	Number of Fillings.	Average. Air for 400 gals. sewage. [*Cu. ft.*]	Average. Period of aeration. [*Hours.*]	Average. Stability. [*Per cent.*]	Nitrogen in sludge. [*Per cent.*]
1	Oct. 4	0	1	750	4.0	0	3.6
2	Oct. 5	1	4	520	4.5	5	4.4
3	Oct. 6	2	7	380	4.5	8	4.2
4	Oct. 7	3	10	630	4.5	10	5.3
5	Oct. 8	4	13	510	4.8	15	4.9
6	Oct. 11	7	18	610	5.7	7	5.2
7	Oct. 13	9	24	660	4.6	13	4.8
8	Oct. 19	15	36	920	4.8	54	5.2
9	Oct. 25	21	53	1340	5.5	90	3.9
10	Oct. 27	23	61	1070	4.6	100	4.1
11	Oct. 28	24	65	690	4.5	96	4.1
12	Nov. 2	29	82	1080	5.6	100	4.0
13	Nov. 5	32	89	1280	5.6	99	4.1
Average (excluding first day)...............				800	4.9	...	4.5

Interesting features noted were the high nitrogen (3.6 per cent) in the sludge after the first aeration, the rapidity with which it increased, reaching its maximum (5.3 per cent) in three days, and the variations in the content of nitrogen. Simultaneous with the decrease in nitrogen in sample 9 there was a considerable increase in the time of aeration and in the amount of air which had been applied. This suggests that the content of nitrogen of the sludge is affected by the amount of aeration; that longer aeration decreases the percentage of nitrogen present as well as the amount of sludge.

The second series of samples was collected from tank C from January 6-25. During this test the sewage was changed 57 times, usually four times a day. From the seventh day, January 13, until 8 a. m. on the tenth day, January 17, no sewage was added, since the sewage had backed up in the sewer to such an extent that it could not be opened to clean out the clogged intake pipe. During this time the sludge alone was aerated. An average of 590 cubic feet of air per gallon and 5.1 hours' aeration were used during each aeration period. The raw sewage applied was very dilute and contained considerable grit. Determinations of ammonia nitrogen, nitrite and nitrate nitrogen and suspended matter were made on each raw sewage and effluent. The nitrogen values of the sludge showed the same characteristics (see Table 12) as were shown in the first series, with the exception that the decrease in nitrogen on prolonged aeration was not so marked.

The third series of samples was collected from tank C from March 9-23. An average of 700 cubic feet of air per gallon and 4.9 hours' aeration were used during each aeration period. Determinations were made of ammonia nitrogen, nitrite and nitrate nitrogen, stability,

TABLE 12.—CONTENT OF NITROGEN OF SAMPLES OF SLUDGE COLLECTED FROM TANK C, JANUARY 6-25, 1916.

Sample No.	Date.	Time.	Number of Fillings.	Average. Air for 400 gals.	Average. Period of Aeration.	Nitrogen in Sludge.	Remarks.
		[Days.]*		[Cu. ft.]	[Hours.]	[Per cent.]	
1	Jan. 6	¼	1	890	5.5	3.40	Very much.
2	7	1	5	580	4.4	3.80	Rain, dilute sewages.
3	8	2	8	370	5.8	4.20	
4	10	4	14	700	6.8	4.60	
5	12	6	21	540	5.1	4.70	
6	13	7	25	620	4.5	4.90	
7	17*	10¾	28	500	5.0	4.60	*Sludge alone aerated 74 hours before this sample was taken.
8	17	11	29	630	5.0	4.90	
9	18	12	33	1010	4.5	4.90	
10	19	13	37	570	4.5	4.80	
11	20	14	41	520	4.5	5.10	
12	21	15	45	460	4.5	4.90	
Average (excluding first day)				590	4.9	4.6	

suspended matter, and the total organic nitrogen of the raw and filtered sewage. Sludge was collected and analyzed as before with additional determinations of phosphorus (P_2O_5), carbon (C) and fat. Carbon was determined by fusion of the sample in a bomb with sodium peroxide, thus converting all carbon into carbonate. The fusion was dissolved in water, carbon dioxide was liberated by HCl, and measured in the Parr apparatus. Total carbon was calculated from the data thus obtained (see Table 13). The same rapid increase in nitrogen in the first few days was very apparent. The effect of long aeration was shown more markedly, the content of nitrogen being reduced from 5.7 per cent in sludge 7 to 4.9 per cent in sludge 8.

Under average conditions 5.1 per cent nitrogen was obtained in the sludge.

The content of nitrogen of the sludge increased very rapidly, the increase during the first day amounting to from 0.4 to 1.5 per cent.

TABLE 13.—ANALYSES OF SAMPLES OF SLUDGE COLLECTED FROM TANK C, MARCH 9-23, 1916.

Sample No.	Date.	Time.	Number of Fillings.	Average. Air for 400 gals.	Average. Period of aeration	Nitrogen in sludge.	Carbon in sludge.	Ratio C:N.	P_2O_5 in sludge.	Fat in sludge.
		[Days.]		[Cu. ft.]	[Hours.]	[Per cent]	[Per cent]		[Per cent.]	[Per cent]
1	March 9	¼	1	460	5.0	2.94	44.2	15.0	1.70	22.9
2	10	1	5	560	4.4	4.29	43.8	10.2	2.27	....
3	13	4	14	690	6.5	4.41	42.4	9.6	2.66	18.1
4	14	5	18	480	4.5	5.03	40.1	8.0	2.77	16.4
5	15	6	22	640	4.5	5.08	40.0	7.9	3.32	14.6
6	16	7	26	670	4.5	5.57	40.9	7.3	3.46	13.0
7	17	8	30	800	4.5	5.66	40.4	7.1	3.33	11.4
8*	20	11	35	930	6.2	4.93	38.6	7.8	2.77	13.0
9	21	12	39	620	4.5	5.30	39.0	7.3	2.88	12.1
10	22	13	43	930	4.5	5.13	....	...	3.03	10.9
11	23	14	47	850	4.5	5.52	....	...	3.11	9.6
Average, (excluding first day).				700	4.9	5.10	41.0	8.1	2.96	13.7

*Sludge alone aerated.

After the first day it fluctuated between 3.8 per cent and 5.7 per cent and was decreased by excessive aeration or by large quantities of grit.

Two reasons have been offered to explain the high nitrogen value of activated sludge.

The first explanation is that the colloidal matter of sewage is retained in the sludge and incorporated with it. It has been shown experimentally that the nitrogen in activated sludge is equivalent to the amount present in the suspended matter of the sewage from which the sludge was formed. In the third series (see Table 13) determinations of suspended matter in the raw sewage and total organic nitrogen in the raw and filtered sewage were made. The nitrogen in the suspended matter was equal to the difference between the nitrogen in the filtered sample and that in the unfiltered sample. The average value of the nitrogen in the suspended matter in the 46 raw sewages applied was 5.15 paints per million. The average amount of suspended matter was 121 parts per million. Therefore, 4.2 per cent of the suspended matter was nitrogen.

Reported analyses of sludges obtained from normal sewages by plaint sedimentation usually give less than 3 per cent for the content of nitrogen.[16, 19] Because of this low nitrogen value such sludges are considered of little value as fertilizers.

It is probable that the coarser suspended matter, which settles out to form such sludge, is low in nitrogen, while the finely divided, colloidal matter is relatively high in nitrogen. This colloidal matter is not removed from the first effluents, and accordingly the sludge at the beginning of operation is low in nitrogen. As more colloidal matter is removed, the nitrogen increases finally reaching a maximum when all of the colloidal matter is retained in the sludge.

Lederer[17] has shown that the colloidal matter is more unstable than the "settleable solids," and this fact indicates that it is higher in nitrogen.

The second explanation for the high nitrogen value of activated sludge was suggested by Adeney.[1] He has shown that oxidation of the organic matter of sewage proceeds in two steps, first, the fermentation of carbonaceous substances, and second, the oxidation of nitrogenous substances. The reaction,

carbonaceous matter + oxygen = carbon dioxide,

proceeds more rapidly than

nitrogenous matter + oxygen = nitrate nitrogen.

It is probable that the high nitrogen value of activated sludge is obtained by both the methods indicated—that is, by complete removal of suspended matter, and by the "burning out" of carbon.

Content of carbon. The contents of carbon of the sludges obtained in the third series during the first days (see Table 13) were higher than those for the later sludges. The ratio of C: N decreased greatly. In the first sludge the ratio was 15.0, but after a week's operation it had dropped to 7.2. This agrees with the theoxy that the increase in the proportion of nitrogen in the sludge is caused by the decrease in the carbon.

Content of phosphorus. The value of activated sludge as a fertilizer may depend to some extent upon its content of phosphorus. Phosphorus in a series of eleven sludges follows the same variations as nitrogen (see Table 13). The same theories that account for the accumulation of nitrogen in the sludge are also applicable to phosphorus.

Proportion of suspended solids retained. During the test from January 6-25, 16.2 pounds of dry sludge were recovered from 22,200 gallons of sewage. The average quantity of suspended matter in the raw sewage was 104 parts per million. Since the effluent was passed through a 16-mesh screen it was approximately free from suspended matter. All of the suspended matter of the raw sewage must have remained in the tank, or must have been removed by liquefaction of the sludge. If all remained 22,200 gallons of sewage containing 104 parts per million suspended matter should have given 19.1 pounds of dry material. Since only 16.2 pounds or 85 per cent were recovered, 2.9 pounds or 15 per cent must have been liquefied.

During the test from March 9-23, 13.6 pounds of dry sludge were recovered from 18,400 gallons of sewage. The average quantity of suspended matter in this sewage was 121 parts per million, or equivalent to 18.4 pounds of dry material. The 13.6 pounds then represents a recovery of 74 per cent.

It is interesting to compare this removal of suspended solids with that obtained by plain sedimentation. It has been found that a certain amount of the finely divided suspended matter of sewage can not be removed even with prolonged sedimentation. This suspended matter is in a colloidal state, forming a hydrogel which is not precipitated by plain sedimentation.

Fuller[12] states that only 70 per cent of the suspended matter in the sewage of Columbus, Ohio, could be removed by plain sedimentation. The remaining 30 per cent passed off in the effluent unless removed by special treatment.

The removal of this finely divided suspended matter is one of the most advantageous features of the activated-sludge process. The effluents are practically free from colloidal matter and nearly 100 per cent of the suspended solids is removed.

Activated sludge has been found valuable as a fertilizer.[4] It is undoubtedly worth recovering because of its high content of nitrogen and phosphorus. This fact gives a different aspect to the question of sludge disposal. In former processes, a small amount of sludge was desired and all possible means for liquefaction were used. In the activated-sludge process all possible means should be used to recover the suspended matter. A recovery of 75-85 per cent is desirable and even higher yields may be possible.

DEWATERING OF ACTIVATED SLUDGE

As the sludge was taken from the tanks it had the appearance of a flocculent precipitate of ferrous-ferric hydroxide. It usually contained 98-9 per cent of water and on standing settled to some extent. After three or four hours, however, the sludge became filled with bubbles of gas from anaerobic decomposition, which caused it to rise to the surface. In this condition it contained 97-8 per cent of water and had the appearance of a hydrogel. Upon further standing it became septic and very colloidal.

The simple sludge-drying bed of sand and gravel was constructed as described on page 100 for dewatering the sludge. In warm, dry weather the bed gave fairly satisfactory results. The sludge dried to a tough, leathery consistency, and had to be dried further on the steam bath before it could be ground. If a rain occurred while the sludge was on the bed, water would not filter through the partially dried sludge but accumulated on the surface of the bed. This had to be removed by decantation or by evaporation.

In the winter it was impossible to dry any sludge on the bed. Alternate freezing and thawing prevented drainage through the sand, and snow and rain kept the sludge wet.

In order to obtain a sludge in marketable condition some degree of heat drying is necessary. The amount of fuel required for drying varies with the amount of water contained in the sludge. Grossman[13] has derived formulae and compiled tables showing the amount of water that must be evaporated from sludges containing varying amounts of water.

If x is the percentage of solid matter and y the amount of water in tons to be evaporated to yield one ton of dry sludge, then

$$y = \frac{100}{x} - 1.$$

If m is the price of coal in dollars per ton, n is tons of water evaporated per ton of coal, and z = cost of drying sludge containing x per cent of solid matter to dryness, then

$$z = \frac{m}{n}\left(\frac{100}{x} - 1\right).$$

Assuming that one ton of coal will evaporate six tons of water from sludge, and that the cost of coal is $1.25 per ton, he has calculated the cost, of drying sludges containing from 5 to 50 per cent of solid matter (see Table 14).

TABLE 14.—CALCULATED COST OF COAL REQUIRED TO PRODUCE ONE TON OF DRY SLUDGE FROM SLUDGES CONTAINING 5-50 PER CENT OF SOLID MATTER.

Solid matter. [Per cent.] (X).	Amount of water to be evaporated. [Tons.] (Y).	Cost of coal required.[a] (Z).
5	19	$3.96
10	9	1.88
15	5.7	1.17
20	4	.84
25	3	.63
30	2.3	.49
35	1.9	.39
40	1.5	.31
45	1.2	.25
50	1.0	.21

[a]Calculations based on assumption that one ton of coal at $1.25 will evaporate six tons of water from sludge.

It will not pay to reduce the water in the sludge by mechanical means to less than 70 per cent, if the sludge must be subsequently dried by heat. A sludge with 80 per cent of water could be very economically dried but satisfactory results might be obtained for sludges containing between 70 and 80 per cent of water.

Precipitants. In order to reduce the water in the sludge to such an extent that drying by heat could be used economically, the effects of several precipitating agents upon a fresh sludge containing 98 per cent of water were studied (see Table 15).

Sodium phosphate is apparently a very good precipitant but the results obtained with 5 grains per gallon even after 24 hours' settling do not warrant its use.

The sludge contained two grams of solids and 98 grams of water. If the volume of water in the sludge is reduced 45 per cent by the precipitant there will be 2 grams of solids in the remaining 55 grams

TABLE 15.—THE EFFECT OF CHEMICAL PRECIPITANTS UPON ACTIVATED SLUDGE.

Precipitant.	Per cent reduction in volume of sludge after settling for		
	2 hours	3 hours	4 hours
Sodium Phosphate Na_3PO_4 5 grains per gallon	15	20	45
Lime and iron $CaO + FeSO_4$ 5 grains per gallon	15	18	44
Lime CaO 10 grains per gallon	12	16	41
$Al_2(SO_4)_3$ 5 grains per gallon	8	12	35
Control	6	10	26

of sludge, and the water in the sludge has only been reduced from 98 to 96.4 per cent.

It is apparently futile to attempt to reduce the content of water of sludge by precipitants. Precipitants may alter the physical character to such an extent that it may be filter-pressed or dried more easily. If this is possible precipitants must be chosen that will add to the value of the dried sludge when used as a fertilizer.

Limestone and rock phosphate, substances which do not react with the substances dissolved in water to form a floc, added in the same manner had no noticeable clarifying or coagulating effect.

Filter-presses. Attempts were made to dewater the sludge by filter-pressing. The smallest Sperry filter-press was used. This was the usual hollow-frame press, into which the 'sludge was fed from a drum under air pressure of 70 pounds. Satisfactory results were not obtained. Filter-pressing the sludge after the addition of lime was next tried because of the cheapness of lime, and its use in de-odorizing septic sludge.

On February 17, 17,000 grams of sludge were treated with 20 grains per gallon of lime. After pressing for 4 hours at 70 pounds-no cake was formed and only a slimy mass remained in the frame.

These experiments and a number of others which followed showed that it was practically impossible to obtain a good cake either with or without the addition of lime. The filter-cloth becomes clogged with an impervious layer of sludge, and at 70 pounds' pressure no more water could be forced through it. Lime does not seem to change the character of the sludge so that it will not clog the filter-cloth.

Filtros-plate filters. Two 6-inch Filtros plates cemented into a frame were lowered into the sludge and suction applied to an outlet between the plates. A very thin film of solid matter soon covered the plates, and after it had been formed no more water could be drawn through it. This device, intended to stimulate the action of a large-scale device called the "Robacher wheel," gave only unsatisfactory results.

Centrifuges. Two small centrifuges, one of the low-speed, basket type, the other of the high-speed, bottle type, were available for the experiments.

The basket of the low-speed machine was 8 inches in diameter and 6 inches deep, and the periphery was perforated with numerous holes one-sixteenth of an inch in diameter. The machine was lined with a strip of muslin cloth covering the holes. Approximately 3,500 grams of 98-per cent sludge were put into the centrifuge and, after 15 minutes, 700 grams of 91-per cent sludge were obtained. The effluent was very dark-colored, but the cake was firm and of uniform consistency.

The high-speed, bottle-type machine reduced the moisture from 98 per cent to 92 per cent in three minutes and gave a clear supernatant liquid.

Considering the crudeness of the basket-type centrifuge used, the results obtained were promising, and such an apparatus, in a more efficient form, should reduce the water in the sludge to 80 per cent. In order to be economical, an automatic arrangement for removing the cake must be provided. Such machines are not made in this country, but have been in use in Germany for a number of years.

The most successful apparatus of this type is the Schafer-ter Meer centrifuge[14] built by ter Meer at Hanover according to the design of Schafer, city engineer of Frankfort. This machine consists of a revolving drum mounted on a hollow vertical axis and surrounded by an outer casing.

The wet sludge enters the center of the revolving hollow axis through an overhead inlet pipe while the machine is in motion. Six radial compartments of 3-liters capacity are attached to the axis, and the inner and outer peripheries of these compartments are closed and opened by slide valves controlled by oil under pressure. On the sides of the compartments are numerous slots 10 by 0.5 millimeters.

The operation is intermittent. Sludge is admitted from the hollow shaft. The heavier particles are thrown against the outer part of the cells and the water escapes through the slots in the sides. The cells are filled with sludge in 2-3 minutes. The inner valves are then closed automatically and after a number of revolutions of the drum the outer valves are opened. The dried sludge is thrown from the cells and falls down onto a belt conveyor. A star-shaped scraper mechanically cleans the sides of the cells after the sludge has been thrown out. This entire cycle requires but 2½-3½ minutes and the period for a dilute sludge is somewhat longer than for a more concentrated one. The drum makes 750 revolutions per minute.

The apparatus will treat approximately 4 cubic yards, or 6,800 pounds of a 92-per cent sludge per hour. The discharged sludge averages 60-70 per cent water, and is crumbly and odorless, except in very warm weather, when a slight odor is noticeable. The effluent is turbid and must be passed through sedimentation basins in order to give a clear liquid.

The machine uses 6.4 kilowatts, and the cost including depreciation of producing one ton of dried material (60-70 per cent of water) is $0.36. Each machine costs $5,500.

If such machines be tried out on a large scale they may be found to be applicable to the drying of activated sludge.

The economic success of the activated-sludge process will depend to a great extent on the solution of the problem of drying the sludge cheaply and easily. Although the disposal of the sludge has been the unsolved problem of present-day methods of sewage disposal, it is very likely that an effective method of dewatering activated sludge will be found. Its value as a fertilizer offers a greater incentive for its recovery than for recovering other kinds of sewage sludge. With nitrogen at 20 cents a pound, a sludge containing 5 per cent of nitrogen in an available form should be worth $20 a ton. Experiments by Bartow and Hatfield[4] have shown that the nitrogen is very available and that activated sludge may be considered at least as a medium-grade fertilizer. Considering this fact, it should not be classed in the same category as septic-tank sludge, Imhoff-tank sludge, and other sewage sludges, but should be classed with much higher grade materials such as fish-scrap, tankage, and dried blood. If some satisfactory method of reducing the moisture to 70-80 per cent is developed, final drying may certainly be carried out by some form of hot-air dryer.

COST OF THE ACTIVATED-SLUDGE PROCESS

The cost of constructing and operating activated-sludge plants has not been considered a part of this investigation, which has been confined more or less exclusively to the phases of chemical and biological interest and significance. The data which have been presented on such features as the accumulation of sludge, the amount of diffusion area required, the amount of air necessary, and the amount of nitrogen in the sludge, are of interest and value to the designer and operator of large-scale plants. Cost data in order to have the proper weight and significance must be secured by operation on a large scale.

A continuous-flow plant, having an estimated capacity of 200,000 gallons a day, has been built by the State Water Survey for the purpose of securing such data.

A plant with an estimated capacity of 2,000,000 gallons a day has been constructed at Milwaukee, Wis., and was operated during the winter of 1915-16.[15]

At Cleveland, Ohio, a plant with an estimated capacity of 1,000,000 gallons a day was put into operation during the latter part of January, 1916.[14]

Operation of these plants will determine whether or not the activated-sludge process is a success financially.

SUMMARY

1. In the aeration of sewage there is almost quantitative oxidation of ammonia nitrogen to nitrite nitrogen followed by oxidation to nitrate nitrogen. From ten to twenty days are required. In the aeration of sewage in contact with activated sludge, ammonia nitrogen is oxidized to nitrate nitrogen in from four to five hours. Nitrite nitrogen is evidently oxidized to nitrate nitrogen almost as rapidly as it is formed.

2. Satisfactory activated sludge can be obtained with six-hour aeration periods without complete nitrification from the beginning of the operation.

3. In a small tank the equivalent of 1,300 pounds of dry sludge per million gallons of strong sewage was obtained. In larger tanks 740 to 1,150 pounds of dry sludge per million gallons of average sewage were obtained.

4. In the presence of 25 per cent of sludge, weak sewage was well nitrified in four hours with one cubic foot of air per gallon of sewage. Normal sewage required 4-5 hours aeration and 1.3 cubic feet of air per gallon of sewage. Strong sewage required more than 5 hours' aeration and more than 1.5 cubic feet of air per gallon of sewage.

5. Better results were obtained when one-third of the floor surface was covered with porous plates than when all, or one-ninth of the floor surface, was covered.

6. The nitrogen in the sludge increases by from one-half to one and one-half per cent per day until an average of 5.1 per cent of

nitrogen is obtained. Excessive aeration decreases both the total quantity of the sludge and its percentage of nitrogen.

7. The content of phosphorus pentoxide ($P_2 0_5$) varies in the same way as the nitrogen, reaching an average at about 3 per cent.

8. Dewatering the sludge is a problem which has not yet reached a satisfactory solution, although small-scale experiments with centrifuges have given promising results. It has been practically impossible to obtain a solid cake by filter-pressing the activated sludge, and experiments with precipitants and Filtros-plate fiters also gave unsatisfactory results.

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RADIOACTIVITY OF ILLINOIS WATERS.*

By Clarence Scholl

During his visit to the United States in 1902, J. J. Thomson[120] reported that the research men of Cavendish laboratory of London had separated a very active gas from a deep well water. At Professor Thomson's suggestion Bumstead and Wheeler[26] investigated the waters of New Milford and New Haven, Connecticut, and found that these two waters contained gases whose activity was six to eight times the normal air leak of an electroscope. Similar research made by other investigators,[1,3,29,36,56,72,115] upon European waters, showed that the active gases occurred universally but varied in quantity in different localities. As there was no standard of activity at that time no quantitative measurements were made; the period of decay of the active material was found to correspond in most cases to the decay period of radium emanation.

Boltwood[17] in 1904, and Boltwood and Rutherford[19] in 1906, investigated the proportion of radium and uranium in radioactive minerals and found the ratio of radium to uranium to be constant, 3.4 x 10-7 grams of radium per gram of uranium. Lind and Whittemore[69] confirmed this ratio in 1915. As the amount of radium emanation in equilibrium with radium is constant, the amount of radium emanation is, therefore, proportional to the amount of uranium. Boltwood[15] suggested that the quantity of radium emanation set free when a known weight of a natural uranium mineral is dissolved in a suitable reagent, be taken as a standard of radioactivity.

In 1905 he used this standard in investigating the activity of the very active thermal spring of Hot Springs, Arkansas.[18] Boltwood's emanation standard was adopted by Moore and Schlundt in their investigations of the waters of Missouri[82] (1905), and the thermal waters of the Yellowstone National Park[83] (1909) ; by Shrader[111] in the investigation of waters near Williamstown, Massachusetts (1914); by Moore and Whittemore[84] in the investigation of Saratoga Springs, New York (1914); by Ramsey[91] in the investigation of the waters of Indiana and Ohio (1915); and by Perkins[89] in the investigation of the waters of Rhode Island (1915).

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Radium emanation, which causes the radioactivity of waters, is formed by the decomposition of radium, which may or may not be present in the water. The emanation is dissolved by the water in its passage through the ground.

Radium emanation is the sixth element in the list of active elements compiled by Rutherford,[97] given in Table 1.

TABLE 1.—RUTHERFORD'S LIST OF RADIOACTIVE ELEMENTS.

Element	Radiation	Half life period
Uranium	α	6×10^9 years
Uranium X	$\beta+\gamma$	24.6 days
Uranium Y	β	1.5 days
Ionium	α	Greater than 20,000 years
Radium	$\alpha+$ slow β	2,000 years
Emanation	α	3.85 days
Radium A	α	3 min.
Radium B	$\beta+\gamma$	26.8 min.
Radium C_1	$\alpha+\beta+\gamma$	19.5 min.
Radium C_2	β	1.4 min.
Radium D	slow β	16.5 years
Radium E	$\beta+\gamma$	5 days
Radium F	α	136 days

Radium salts, although seldom found in natural waters have been found in waters in the Tyrol[7] district of the Alps and in the Doughty Springs[47] of Colorado. Their absence in most natural waters is explained by the chemical properties[113] of the element. It is in the second group of Mendeljeff's periodic system as the highest member of the barium series. Radium sulfate is, therefore, even more insoluble than barium sulfate; even radium chloride remains dissolved only in a solution strongly acidified with hydrochloric acid. Since many natural waters are alkaline and many contain large quantities of sulfate and chloride, radium salts can not be present in solution. Most waters, therefore, contain only emanation.

METHODS OF DETECTION AND MEASUREMENT.

Three general methods have been employed for determining the presence of radioactive material: (1) the photographic method, (2) the luminous screen method, and (3) the electrical method.

1. The photographic method[27] was used very extensively in the early measurements of activity. It depends on the darkening of a photographic plate when exposed to the action of the active substance. The method may be used with distinct advantage in studying the curvature of the path of the rays when under the influence of a magnetic or electric field. As a quantitative method, however, it is open to many objections. The active material must be in a solid state of aggregation, and usually a day's exposure to a weak source of radiation

is required to produce an appreciable darkening of the photographic film. Since darkening of a photographic plate may be produced by many agents which do not give out radioactive rays, special precautions are necessary during long exposures. Another and more important difficulty, however, lies in the inaccuracy inhering in measurements of density in the photographic impression from which the intensity of the radiation must be calculated.

2. The luminous screen method[28,35] depends upon the appearance of a brief illumination when an alpha ray from an active material strikes a screen of sensitive material such as barium platinocyanide, willemite, diamond, or zinc sulfide. The amount of active material present can be calculated from the number of illuminations in a given time. The method has been used extensively, but its application is limited by the low intensity of some of the illuminations. The luminosities produced in barium platinocyanide, willemite, and diamond are of service only in qualitative work. Table 2 gives the relative luminosity of five substances.[100]

TABLE 2.—RELATIVE LUMINOSITY OF VARIOUS SUBSTANCES USED IN THE LUMINOUS SCREEN METHOD.

Substance	Without Screen	Through Black Paper
Zinc blende	13.36	0.53
Barium platinocyanide	1.99	0.10
Diamond	1.14	0.01
Potassium uranium double sulfate	1.00	0.31
Calcium fluoride	0.30	0.01

The luminosity produced in zinc sulfide has proved invaluable in quantitative work, since it affords a direct method of counting the number of alpha particles emitted from an active solid substance, but it is not applicable to waters, whose activity is due to gases.

3. The electrical method [75,90,103,114,119] is based on the ionization of gases by radioactive substances. The production of positively and negatively charged particles in a gas is directly proportional to the number of rays emitted, to the quantity of radioactive material, and to the current of electricity which can pass through the gas. The strength of this current of electricity is the quantity usually determined: the maximum current produced when the gas is electrically saturated is always taken.

The strength of the current can be measured with a sensitive electrometer.[2,25,37,71] But in most cases, since the material is but slightly active, it is more convenient to use an electroscope.[17,63,125,126] Since the capacity of an electroscope is nearly constant, the average rate of movement of the leaves is directly proportional to the rate of discharging the system, to the amount of electricity passing through the gas, to the ionization of the gas, to the number of rays emitted, and to the amount of active material present. If a solid substance is placed between two horizontal plates, the lower connected to the earth, the upper connected to the leaf system of a charged electroscope the activity can be determined directly by observing the rate of fall of the leaf with a telemicroscope provided with a uniform scale in the eyepiece. The observed fall must be corrected by subtracting the natural leak of the apparatus when no radioactive material is present. An electroscope of this kind is especially suited for the measurement of activity caused by alpha rays, (see Figure 1.)

A modification of this electroscope can be used to determine extremely small currents of electricity with accuracy. This modification first used by Wilson[125] in the study of the ionization of air, has the gold leaf attached to the vertical upper plate (see Figure 2). The whole system of plate and leaf is insulated within the containing vessel after charging by means of a movable wire passed through the walls of the vessel and touched to the upper plate whenever desired.

RADIOACTIVE STANDARDS.

A great many measurements of the activity of spring and well waters have been made, but there is no general comparison of the results of various investigators. Of the many standards suggested, but three are now in general use: the McC'oy[79,80] urano-uranic oxide standard, the Boltwood[16,19,22] equilibrium emanation standard (the curie), and the C. G. S. absolute standard.

McCoy, Ashman, and Boss[80] have recently studied the relation between the McCoy urano-uranic oxide standard and the C. G. S. unit by using uniform layers of specially prepared oxide.[79] They found the ionization currents due to the alpha rays from a thick film of urano-uranic oxide to be 5.79×10^{-13} amperes or 1.737^{-3} C. *G.* S. electrostatic units per square centimeter. This value is constant and capable of being reproduced. The specific activity of uranium,[78] defined as the total ionization current from one gram of uranium when all the radiation is absorbed in the air, is 796 McCoy units. The total ionization currents from one gram of uranium free from its products is then 1.38 C.G.S. electrostatic units.

Rutherford[99] has shown that one gram of uranium emits 2.37×10^4 alpha particles per second. Each particle has a range of 2.50 centimeters and produces a total of 1.26×10^5 ions. Each of these ions [98] has an elementary charge of electricity of 4.65×10^{-10} C. G. S. electrostatic units. Thus one gram of uranium is equivalent to $2.37 \times 10^{4} \times 1.26 \times 10^{5} \times 4.65 \times 10^{-10} = 1.38$ C. G. S. electrostatic units. This agrees with the figure cited above..

Boltwood[20] has shown that if the activity of uranium free from its product be taken as 1.00, the relative values of the activities due to alpha rays of the different elements in equilibrium in a uranium mineral are as follows:

Uranium	1.00
Ionium	.34
Radium	.45
Radium emanation	.54
Radium A	.62
Radium B	.04
Radium C	.91
Radium F (Polonium)	.46
Actinium and its products	.28
Total activity	4.64 x Uranium

In the determination of the activity of a sample of uraninite by means of the emanation method an activity is separated equivalent to that of radium emanation, or 0.54 of the activity of the uranium present. The decay of radium emanation into radium A, B, and C however, is so rapid that in the determination not only the effect of the radium emanation is measured but also the effect of radium A, B, and C. The effect of radium F (Polonium) is small and can be neglected. The sum of these activities will be 0.54 + 0.62 + 0.04 + 0.91 = 2.11 times that of uranium free from its products, if all activity is absorbed in air.

Hence 1.38 x 2.11 = 2.90 C. G. S. electrostatic units is the total equivalent of one gram of uranium in uraninite, if the emanation is calculated at its maximum activity.

Duane and Laborde's[32] formula for the relation between a maximum current and that obtained in any electroscope is

$$I_0 = \frac{I}{\left(1 - 0.57\,\frac{S}{V}\right)}$$

(I is the electric current in electrostatic units in an electroscope with a surface S and a volume V. I_0 is the true equivalent in electrostatic units). Solving this equation for the current of the electroscope, we get

$$I = I_o\left(1 - 0.57\frac{S}{V}\right)$$

Substituting the values of S and V for the gas electroscopes, we get

$$I = 2.90\left(1 - 0.57\frac{36\pi}{27\pi}\right)$$

I = 0.696 electrostatic units.
The activity of one gram of uranium, therefore, equals 0.696 electrostatic units in the system.

This factor was used in changing data from the uraninite standard to the electrostatic unit standard.

PLAN OF WORK.

The purpose of this investigation was to determine quantitatively the radioactivity of Illinois waters and to study the relations, if any, between the radioactivity, the dissolved mineral constituents, and the geographical and geological locations from which the waters were obtained.

The electrical method of measuring radioactivity was adopted for use in the investigation. The first electroscope tried, made according to specifications of some European investigators,[39] was found unreliable for small quantitative measurements, when tested with uraninite. A modification of an electroscope designed by Wilson,[125] was tested and found satisfactory for the measurement of radioactivity of gases, and an electroscope with an ordinary leaf system was adopted for testing the activity of solids.

Some of the waters were analyzed in the field; samples of the others were collected, sealed, and shipped to the laboratory where they were analyzed immediately. The results of the analyses made in the laboratory were corrected for the decay of activity by means of the formula $I_0 = I_t{}^{c-rt}$ in which I_0 is the initial activity, I_t is the observed activity at the time of making the analysis, t is the time after the water was collected, and r is the radioactive constant.[102] This has a value of .0075 when t is expressed in hours, or 0.1800 when t is expressed in days.

Whenever the presence of radium salts was suspected, the water was evaporated to about 100 centimeters, acidified with hydrochloric acid sealed, and kept for thirty days in order to allow, the emanation to again reach a maximum. The activity if any, when again tested, was due to the radium present in the original sample.

Samples of sediment in the waters were examined in a similar manner but none were found to be radioactive.

The waters were analyzed for their mineral constituents by the methods advocated by the American Public Health Association[6] and the Illinois State Water Survey.[58]

APPARATUS

Electroscope for gases

The electroscope, constructed by the Central Scientific Company, is an adaptation of Boltwood's modification[17] of Wilson's electroscope.[125] (See Figures 5 and 6). It consists of a cylinder 8 centimeters long and 15 centimeters in diameter, fitted at each end with a piece of plate glass. The side of the cylinder is securely fastened to a wooden base by means of an iron stand four inches high. A short wide glass tube covers a hole in the top of the cylinder. A brass cap surmounts the glass tube. A short brass rod is screwed into the cap. A piece of amber, screwed on the lower end of rod, supports a gold or aluminium leaf plate and insulates the leaf and plate within the cylinder.

The device for charging is a special feature. An arm is fastened on the brass rod and supports a soft iron wire extending below but not touching the amber insulator. The leaf is charged to the same potential as the brass cap above, by bringing a magnet near the glass and forcing the wire against the leaf plate. Two air-tight stopcocks, one at the top and one at the bottom, are for the admission of gases. All joints are made air-tight by sealing with wax and rosin. An aluminium leaf, 5 by 50 millimeters, was used rather than the gold leaf, which gave trouble continually. It was fastened to the plate by placing a streak of glue across the upper part of the plate and then pressing the leaf firmly against it. The original aluminium leaves have withstood transportation by rail to various parts of the State and are still in good condition.

The electroscope was charged by the following method: The iron wire was forced with a magnet against the leaf plate. A charged vulcanite rod was brought near the cap until the desired potential was obtained. The iron wire was allowed to swing free by removing the magnet; the vulcanite rod withdrawn; the cap earthed for an instant, and the leaf, insulated within the cylinder, was thus charged at the desired potential.

A tele-microscope, the eye piece of which contained a scale twelve millimeters long with each millimeter divided into ten divisions, was used to determine the rate of fall of the leaf. A stop watch recording fifths of a second, was used to determine the time interval.

Two U tubes, one containing phosphorus pentoxide (P,O_5), the other containing calcium chloride ($CaCl_2$), were always connected in series with the electroscope, when evacuating or when adding gases, the phosphorus pentoxide tube being between the electroscope and the calcium chloride tube.

Electroscope for solids

The electroscope for measuring the radioactivity of solids was obtained from E. H. Sargent of Chicago. It consisted of a cubical metal box, 4½ inches, fitted on two opposite sides with glass plates which could be raised or lowered. (See Figure 4). An amber ring supported and insulated a leaf below and brass ball above the center of the top. These, with a leaf plate and rod connecting the brass ball, made up the electrical carrying portion of the electroscope. A small copper tray 4x4½ inches held the solid material when it was inserted in the box for the determination. No precautions were taken for drying the material.

STANDARDIZATION OF ELECTROSCOPES.

The methods of measuring radioactivity give relative quantitative values. The activity of some substance is taken, as the fundamental unit and the activities of other substances are compared with it. Fundamental units are the Mache, the curie, and that from uranium. The amount of radium in one gram of uranium in uranium ores, as found by Boltwood[19,21] and Eutherford[101], and later by Strutt[116] and by McCoy[77], is always 3.4×10^{-7} gram. If the emanation from a weighed sample of uranium mineral, whose content of uranium is known from a chemical analysis, is used, we can calculate the radium equivalent of the activity. Thus if we use one gram of mineral containing 25 per cent of uranium the fall of the leaf of the electroscope corresponds to $3.4 \times 10^{-7} \times .25 = 0.85 \times 10^{-7}$ gram of radium. Or if expressed in grams of radium per space per minute, we have

$$\frac{3.4 \times 10^{-7} \times .25}{\text{number of spaces fallen in one min.}} = X \text{ grams of radium in uranium}$$

mineral per space fall per minute. A "curie"[20] is the amount of emanation in equilibrium with one gram of radium. Hence the activity obtained from X grams of radium is X curies of emanation.

Electroscope for gases

A small weighed quantity of the standard sample of uraninite containing 43.6 per cent uranium was placed in a flask, of about 100 cubic centimeters capacity. (See Figure 7). Ten milligrams were usually taken, as this quantity produced a convenient rate of fall of the leaf. The flask was closed with a two-hole rubber stopper; a separatory funnel was fitted in one hole, and an upright condenser in the other. The condenser was connected by a glass tube and stopcock to another flask also fitted with a two-hole stopper. Through one was the connection to the condenser and through the other a glass tube with a stopcock. After the whole apparatus had been made air-tight, it was evacuated by a pump connected to the stopcock. A little dilute nitric acid was added to the uraninite in the flask, and the mixture was then boiled for fifteen minutes. The acid and water rising as vapor condensed in the condenser and returned to the flask. After boiling fifteen minutes, distilled water free from emanation was run into the apparatus through the separatory funnel until the mark was reached. The stopcock was then closed. The emanation with other gases, now in the flask under a fraction of an atmosphere pressure, were introduced into the partially exhausted electroscope and the rate of fall of the leaf determined after 3 to 3½ hours. The fall of the leaf was corrected by subtracting the normal air leak of the electroscope when the gas in the electroscope was free from emanation. The correction was always small and amounted to only 0.003 division per minute for the electroscope. The rate of fall was always

TABLE 3.—STANDARDIZATION OF ELECTROSCOPES FOR GASES.

Date.	Mineral used. (Grams.)	Divisions fall per minute.	Activity per division per minute.	
			(UR^a g.x10^{-4})	(Ra.g.x10^{-10})
		ELECTROSCOPE A		
Oct. 23, 1914	.0299	15.80	8.28	2.81
Oct. 26, 1914	.0301	16.08	8.12	2.76
Dec. 4, 1914	.0253	18.18	6.06	2.06
Dec. 5, 1914	.0069	4.92	6.11	2.08
Feb. 24, 1915	.0078	5.50	6.50	2.21
Sept. 25, 1915	.0078	5.50	6.50	2.21
Dec. 13, 1915	.0074	2.14	15.1[a]	5.13
Dec. 14, 1915	.0113	3.17	15.2	5.17
Jan. 7, 1916	.0159	10.0	6.93[b]	2.36
Jan. 8, 1916	.0082	5.14	6.95	2.36
		ELECTROSCOPE B		
Oct. 23, 1914	.0342	18.28	8.16	2.77
Oct. 26, 1914	.0340	18.28	8.14	2.77
Dec. 4, 1914	.0204	9.92	8.86	3.01
Dec. 5, 1914	.0125	6.70	8.13	2.76
Sept. 25, 1915	.0086	4.55	8.24	2.80
Dec. 13, 1915	.0105	6.00	7.68	2.61
Dec. 14, 1915	.0094	5.40	7.64	2.59
Jan. 7, 1916	.0087	5.00	7.59	2.57

[a]The aluminium leaf was shortened to about one-half its original length.
[b]A new leaf was placed in the electroscope.

taken, when the leaf was at an angle of less than 30° with the plate. The electroscopes were standardized at frequent intervals. (See Table 3).

Electroscope for solids

One-tenth of a gram of the original uraninite was dissolved in a small quantity of nitric acid and evaporated to dryness in a porcelain dish. The residue was taken up with a small quantity of water, transferred to a copper plate, and evaporated to dryness. This plate was then inserted into the electroscope and the rate of fall of the leaf determined. The rate of the normal leak, obtained by exactly the same procedure, but without the uraninite, was subtracted. Thus a fall of the leaf of one millimeter per minute represented 6.2 milligrams of uranium in uraninite. The electroscope was standardized for thorium by' the same procedure used for uranium, except that thorium sulfate and nitrate were substituted for. the uraninite. The standardization data are given in Table 4.

TABLE 4.—STANDARDIZATION OF ELECTROSCOPE FOR SOLIDS.

Date.	Mineral used. (Grams)	Divisions fall per minute.	Activity per division per minute.
		URANIUM DATA	(URANIUM IN GRAMS).
Nov. 19, 1914	0.100 uraninite............	7.06	0.0062
		THORIUM DATA	(THORIUM IN GRAMS).
Dec. 8, 1914	0.274 as sulfate............	3.47	0.078
Jan. 17, 1916	0.1124 as nitrate + 0.5 NaCl..........	1.46	0.077
Jan. 27, 1916	0.0196 as nitrate + 0.2 NaCl..........	0.23	0.085
Jan. 20, 1916	0.196 as n trate............	0.97	0.0202

SEPARATION OF THE EMANATION FROM WATER

The sample of water to be examined for radioactivity was collected in a round-bottom flask holding about 1200 cubic centimeters. A liter was taken except for waters of very high activity in which case half quantities were taken. Great care was exercised to obtain a representative sample of the water. The flask was immediately closed with a two-hole stopper fitted with two glass tubes. Each of these was fitted with a piece of rubber tubing with a pinch cock attached. The flask was then connected to an upright condenser and flask. (See Figure 8). The condenser and flask were evacuated with the pinch-cock closed. The pinch cock was then opened and the water in flask was boiled vigorously for about 20 minutes, after which water free from emanation was then run in through the stopcock as in the process of standardization. The emanation with other gases was then transferred to an electroscope and the activity determined.

TEST FOR THORIUM

After the expulsion of radium emanation in the determination of radioactivity the samples of water were evaporated to dryness. The residues were taken up in a small quantity of hydrochloride acid, transferred to small plates, 4 inches in diameter and one-fourth inch in depth, again evaporated to dryness, and the activities of the residues on these plates[0] were determined in the electroscope for solids. In none of the waters tested was any thorium found.

Portions of the deposits found at some of the springs weretested for activity in the same manner. There was no evidence of thorium.

RADIOACTIVITY ANALYSES

Gas was found escaping from only one water (Alton mineral spring). It was evolved at a rate of about 3 cubic centimeters per minute. No radium or thorium emanation was found in the gas.

Deposits were found only at the Dixon springs of the Ozark uplift. No radium or thorium was found in the deposits.

One hundred and thirty determinations of radioactivity of natural waters were made, and thirty-seven determinations of the radioactivity of residues sealed for thirty days. Twenty-two specimens of the mineral residues were tested for thorium. No thorium was detected in either the residues or waters. Excluding negative and doubtful results, the analyses of sixty-eight waters, whose activity and whose mineral constituents are known, are compared in Table 5.

CLASSIFICATION OF THE WATERS EXAMINED

Natural waters may be classified according to their physical and chemical properties,[49] or according to the geological strata from which they come. Classification by physical and chemical properties, as for example Peale's[50] classification modified by Haywood,[51] have been tried, but have not been found advantageous, since no direct relation has been found between the radioactivity and the classes of water indicated.

Classified according to source, Illinois waters fall in four large groups. (1) Waters from deep rock in the northern part of the state, including waters from the Potsdam and St. Peter sandstones, from the Trenton Galena formation, and from the lower magnesium limestone.

TABLE 5.—RADIOACTIVITY OF SIXTY-EIGHT ILLINOIS WATERS IN COMPARISON WITH THEIR CONTENTS OP CALCIUM AND MAGNESIUM AND RESIDUE ON EVAPORATION.

No.	Date.	Location	Depth Feet	Calcium [Parts per million.]	Magnesium [Parts per million.]	Residue [Parts per million.]	Radioactivity: Uranium 10^{-4} g.	Radioactivity: Radium 10^{-10} G.	Radioactivity: E.S.U. 10^{-3}
		WATERS FROM DEEP-ROCK WELLS.							
1	3-13-16	Alton........	1450	358.4	186.8	16293.5	2.8	0.95	19.6
2	10-29-15	Carbondale...	600	50.0	21.9	3367.5	2.1	0.71	14.7
3	10-29-15	Carbondale...	610	21.4	7.9	2188.5	1.8	0.61	12.6
4	2-17-15	Elgin........	1850	93.6	48.9	600.1	5.2	1.76	35.4
5	2-18-15	Elgin........	1300	80.1	24.0	375.	4.4	1.49	30.8
6	2-15-15	Harvey......	1668	173.5	48.5	1204.2	3.3	1.12	23.1
7	2-25-16	Ottawa.......	400	70.4	84.0	364.	2.7	0.92	18.9
8	2-25-16	Ottawa.......	1800	102.	42.2	3623.	2.1	0.71	14.7
9	2-25-16	Ottawa.......	....	319.	105.	3276.7	2.3	0.78	16.1
10	2-27-16	Ottawa.......	310	58.4	26.	353.	3.6	1.23	25.2
11	2-25-16	Peru.........	1263	51.5	10.5	746.2	3.1	1.05	21.7
12	2-25-16	Peru.........	1400	52.3	21.7	1570.4	2.7	0.91	18.9
13	2-25-16	Peru.........	1390	48.8	22.	811.	2.5	0.85	17.5
14	12- 2-15	Stonefort.....	....	189.3	134.7	2123.6	2.5	0.85	17.5
15	2-24-16	Streator......	640	48.9	11.9	770.6	2.9	0.99	20.3
16	2-24-16	Streator......	540	61.8	6.8	1070.7	2.4	0.82	16.8
17	2-24-16	Streator......	....	46.6	24.6	880.5	1.4	0.48	9.8
18	2-24-16	Streator......	660	56.0	23.9	1099.1	2.2	0.75	15.4
19	2-19-15	Waukegan....	1500	123.9	23.1	532.7	2.9	1.00	20.3
20	2-19-15	Waukegan....	....	7.7	9.1	2189.	2.0	0.68	14.0
21	2-19-15	Waukegan....	....	95.0	49.9	477.5	3.5	1.19	24.6
		WATERS FROM DRIFT WELLS.							
22	2-17-15	Aurora.......	94	72.4	29.5	326.9	4.0	1.36	28.0
23	2-26-16	Bloomington..	170	53.2	28.3	486.8	3.3	1.12	23.1
24	2-26-16	Bloomington..	155	51.0	32.4	421.4	5.3	1.80	37.1
25	12- 3-15	Carrier Mills..	150	38.9	21.8	.....	4.5	1.53	31.5
26	9-28-15	Champaign...	32	112.1	40.6	466.9	2.9	0.99	20.3
27	9-28-15	Champaign...	165	62.4	96.0	350.0	2.5	0.85	17.5
28	9-27-15	Champaign...	165	56.0	26.0	328.7	1.6	0.54	11.2
29	2-18-15	Elgin........	42	74.4	28.8	388.	6.2	2.10	43.4
30	12- 3-15	Harrisburg....	106	56.8	33.8	538.	4.1	1.40	28.7
31	10- 6-15	Homer.......	120	74.7	34.8	482.3	4.9	1.66	34.3
32	10- 6-15	Homer.......	200	67.2	34.8	1466.1	8.4	2.86	58.8
33	10- 6-15	Homer.......	72	78.5	36.1	512.0	6.7	2.27	46.9
34	10- 6-15	Homer.......	86	106.4	20.4	522.	3.2	1.09	22.4
35	2-16-15	Joliet........	155	165.4	107.8	1033.2	8.4	2.86	58.8
36	2-16-15	Joliet........	500	206.4	78.0	1212.5	11.4	3.88	79.8
37	2-16-15	Joliet........	225	394.4	281.5	2647.4	18.7	6.36	130.9
38	10-11-15	Rossville.....	130	57.5	42.9	356.6	1.6	0.54	11.2
39	12- 4-15	Shawneetown.	148	113.9	50.9	552.1	4.9	1.66	32.2
40	12- 2-15	Stonefort.....	25	130.2	97.0	1283.9	4.2	1.43	29.4
41	9-24-15	Urbana......	30	70.9	32.6	345.4	3.3	1.12	23.1
42	6- 1-15	Urbana......	60	105.1	55.3	557.0	3.3	1.12	23.1
43	12- 7-14	Urbana......	...	51.6	26.0	332.3	2.4	0.82	16.8
44	9-29-15	Urbana......	26	68.5	47.0	709.2	2.1	0.7	14.7
45	1-15-15	Urbana......	160	73.5	33.3	394.8	2.4	0.82	16.8
46	10-10-15	Watseka.....	150	41.8	14.2	342.6	3.6	1.22	25.2
47	10- 8-15	Watseka.....	160	47.9	15.9	379.9	4.3	1.46	30.1
		WATER FROM LOWER MISSISSIPPIAN.							
48	10-26-15	Cairo........	824	45.1	12.9	337.7	3.3	1.12	23.1
49	10-26-15	Cairo........	824	45.4	12.8	336.4	2.0	0.68	14.0
50	10-26-15	Cairo........	1040	46.1	13.0	348.8	1.4	0.49	9.8
51	10-26-15	Cairo........	675	63.0	17.9	643.1	4.1	1.39	28.7
52	10-26-15	Cairo........	826	52.9	18.8	435.6	13.0	4.42	91.0
53	10-26-15	Cairo........	800	66.6	21.0	571.3	1.4	0.49	9.8
54	10-26-15	Mound City..	630	45.2	12.5	265.5	2.5	0.85	17.5
55	12- 2-15	Creal Springs.	...	....	....	711.	24.6	8.36	172.2
56	10-27-15	Dixon Spring.	...	41.2	18.2	305.7	18.2	6.19	127.4
57	10-27-15	Dixon Spring.	...	26.4	14.1	232.9	86.1	29.30	602.7
58	10-27-15	Dixon Spring..	...	29.1	13.3	247.0	4.9	1.67	34.3
59	10-27-15	Dixon Spring.	...	28.9	14.2	261.4	4.0	1.36	28.0
60	12-16-15	Dixon Spring.	...	5.1	1.4	62.3	67.0	22.80	469.0
61	12-16-15	Dixon Spring..	...	2.9	0.5	98.1	13.0	4.42	91.0
		SPRING WATER NORTH OF OZARK UPLIFT.							
62	10-28-15	Mt. Vernon...	...	319.1	203.0	2610.1	5.2	1.76	36.4
63	10-28-15	Mt. Vernon...	...	103.8	50.9	1202.6	2.2	0.92	15.4
64	2-25-16	Ottawa.......	...	102.	42.2	3623.	2.1	0.71	14.7
65	2-25-16	Ottawa.......	...	319.0	105.0	3276.7	2.3	0.78	16.1
66	2-25-16	Peru.........	...	52.3	21.7	1570.	2.7	0.91	18.9
67	2-19-15	Waukegan....	...	95.0	49.9	477.5	3.5	1.19	24.5
68	2-19-15	Waukegan....	...	123.9	23.1	532.7	2.9	1.00	20.3

(2) Waters from the drift, including those occurring in glacial drift, alluvial drift and in loess.

(3) Waters from the lower Mississippian, including the deep-well waters south of the Ozark uplift.

(4) Waters from the Ozark uplift, mainly, springs, occurring among the Ozark foot hills of southern Illinois.

DISCUSSION OF RESULTS

The activity of the sixty-eight waters, expressed in terms of the uranium, radium, and electrostatic-unit standards, are exhibited with calcium, magnesium, and residue according to the four geological groups in which the waters are classified in Table 5. No apparent relation exists between the activity and other mineral constituents, so that data concerning them are omitted.

Waters from deep-rock wells have a uniform activity but varying amounts of mineral constituents. Waters from drift wells vary both in activity and mineral constituents. Waters from the lower Mississippian vary in activity but have a uniform amount of mineral matter. Spring waters can be divided in two smaller groups: one with constant activity and varying mineral matter; the other with constant mineral matter and varying activity.

Waters from wells in deep rock

The activities of twenty-one waters from deep-rock wells vary between 0.5 and 1.5 x 10^{-10} gram of radium per liter. The largest number, however, have an activity of approximately 1.0 x 10^{-10} gram of radium per liter. These waters of uniform activity vary widely in mineral constituents, for calcium varies between 8 and 360 parts per million; magnesium between 7 and 187 parts per million, and residue, between 364 and 16,300 parts per million. A water (No. 11 from Peru) with a calcium content of 51.5 parts per million, a magnesium content of 10.5 parts per million, and a residue of 746 parts per million has an activity of 1.05 x 10^{-10} gram of radium per liter, and a much more highly mineralized water (No. 1 from Alton), with a calcium content of 358.4 parts per million, a magnesium content of 186.8 parts per million, and a residue of 16293.5 parts per million, has an activity of 0.95 x 10^{-10} gram of radium per liter, which is practically the same as that of the first water. There appears to be no relation between the activity and the mineral constituents of these waters (See Plate 2).

Waters from wells in drift

The activities of twenty-six waters from drift wells vary between 0.5 and 5.7 x 10^{-10} gram radium per liter. These waters of varying activity vary also in mineral constituents: calcium, between 42 and 395 parts per million; magnesium, between 14 and 282 parts per million, and residue between 327 and 2647 parts per million. The activity of the waters in this group increases with an increase in mineral constituents. (Plate 3 and 4).

A water (No. 38 from Rossville) of the lowest mineral content, having 57.5 parts per million of calcium, 42.9 parts per million of magnesium, and a residue of 356.6 parts per million, has an activity of but 0.54 x 10^{-10} gram of radium per liter, and another water, (No. 37 from Joliet) of the highest mineral content, with 394.4 parts per million of calcium, 281.5 parts per million of magnesium, and a residue of 2647.4 parts per million, has the highest activity, 6.36 x 10^{-10} gram radium per liter. The activities of the two waters are in the same ratio as the like mineral constituents.

In many waters the relation appears to be quantitative. The relation between the activity and calcium in the majority of the waters examined is 56 parts per million of calcium for every 1.0 x 10^{-10} gram of radium.

The relation between the activity and magnesium in the majority of the waters examined is 44 parts per million magnesium for each 1.0 x 10^{-10} gram of radium.

By adding the calcium and magnesium we get in the majority of waters examined 100 parts per million of calcium and magnesium for each 1.0 x 10^{-10} gram of radium.

The relation between activity and residue in most of the waters examined is 400 parts per million of residue for each 1.0 x 10^{-10} gram of radium.

No other relation between the activity and mineral constituents were found, nor was a relation found between the activity and the depth of the well.

Waters from wells in lower Mississippian

The activities of seven waters from the Lower Mississippian vary between 0.5 and 4.5 x 10^{-10} gram of radium per liter, a variation of 1 to 9. These waters have very uniform mineralization, calcium, from 45 to 67 parts per million (a variation of only 1 to 1.5) ; magnesium, from 13 to 21 parts per million, (1 to 1.7), and residue, from 266 to 643 parts per million, (1 to 2.4). The variation of the residues is even less if the sodium chloride is subtracted. (See plate 5).

A water (No. 50 from Cairo), with a content of calcium of 46.1 parts per million, of magnesium of 13.0 parts per million, and a residue of 349 parts per million (residue minus sodium chloride equals 200 parts per million) has the lowest activity of 0.49 x 10^{-10} gram of radium per liter; and another water (No. 52 from Cairo) with practically the same mineral content, having 52.9 parts per million of calcium, 13.8 parts per million of magnesium, and a residue of 435.6 parts per million (residue minus sodium chloride equals 224 parts per million), has the highest activity, 4.42 x 10^{-10} gram of radium per liter, which is nine times that of the first water. There appears to be no relation between the activity of these waters and the mineral constituents.

Waters from springs

The activities of fourteen spring waters vary between 0.8 and 29.3 x 10^{-10} gram of radium per liter. These waters of varying activity have varying mineral constituents; calcium from 3 to 319 parts per million; magnesium, 0.5 to 203 parts per million, and residue from 98 to 2610 parts per million. However, the waters can be divided into two groups, one group, including the springs north of the Ozark uplift, resembles the waters from deep rock wells having constant activity and variable mineral content, while the other includes the springs in the Ozark uplift of variable activity and variable mineral content. (Plate 6).

Springs north of Ozark uplift

The activities of seven springs north of the Ozark uplift vary between 0.7 and 1.7 x 10^{-10} gram of radium per liter, a variation of 1 to 2.4. These waters of rather uniform activity differ widely in mineral constituents; calcium from 95 to 319 parts per million, a variation of 1 to 3.3; the magnesium from 23 to 203 parts per million, a variation of 1 to 9, and residue from 533 to 3623 parts per million, a variation of 1 to 7.

A water (No. 66 from Peru) with 52.3 parts of calcium, 21.7 parts of magnesium and a residue of 1570 parts per million, has an activity of 0.91 x 10^{-10} gram of radium per liter, and another water (No. 65 from Ottawa) of much higher mineral content, with 319.0 parts per million of calcium, 105.0 parts per million of magnesium, and a residue of 3277 parts per million, has an activity of 0.78 x 10^{-10} gram of radium per liter, which is slightly lower than that of the former water. There appears to be no specific relation between the activity of these waters and the mineral constituents. (Plate 6).

Springs of the Ozark uplift

The activities of seven springs in the Ozark uplift vary between 1.4 and 29.3 x 10^{-10} gram of radium per liter, a variation of 1 to 21. These waters of widely varying activity differ in mineral constituents, calcium, from 3 to 41 parts per million, a variation of 1 to 13.7; magnesium, from 0.5 to 18 parts per million, a variation of 1 to 36, residue, from 63 to 711 parts per million, a variation of 1 to 11.3. No uniform relation exists, however, between the activity and mineral constituents, for the water highest in activity (29.3 x 10^{-10} gram of radium per liter for No. 57 from Dixon Spring) is but slightly mineralized, having 26.4 parts per million of calcium, 14.1 parts per million of magnesium, and 232.9 parts per million of residue; the water highest in mineral matter, with 41.2 parts per million of calcium, 18.2 parts per million of magnesium, and 306 parts per million of residue, has a medium activity of 6.19 x 10^{-10} gram of radium per liter (No. 56 from Dixon Spring); the water lowest in activity (1.36 x 10^{-10} gram of radium per liter for No. 59 from Dixon Spring) has a rather low mineral matter, containing 28.9 parts per million of calcium, 14.2 parts per million of magnesium and 261 parts per million of residue; and the water lowest in mineral matter, with 2.9 parts per million of calcium, 0.5 part per million of magnesium, and 98.1 parts per million of residue, has a medium activity of 4.42 x 10^{-10} gram of radium per liter (No. 61 from Dixon Spring). As both the mineral content and the activity is variable there appears to be no relation between the activity of these waters and the mineral constituents. (See Plate 6).

Some of the springs of the Ozark region have the highest activities of any waters in the State, (29.3 x 10^{-10} gram of radium per liter in No. 57 from Dixon spring, 22.8 x 10^{-10} gram of radium per liter in No. 60 from Dixon Spring). Careful search was made for thorium and uranium but none were found. The decay of the activity from four springs was determined during a period of nineteen days and found to be the same as that of radium emanation amounting to 3.85 days per half period. (See Table 6 and Plate 1).

COMPAEISON WITH OTHER AMERICAN AND EUROPEAN WATERS

The activities of typical waters from several localities in America and Europe lie between 100 x 10^{10} gram of radium per liter and zero. (See Table 7). The most active waters are found in Colorado, Tyrol, Bohemia, and in other localities where uranium deposits occur. No traces of uranium deposits have been found in Illinois. Next to the waters from Uranium regions the Imperial spring at Hot Springs, Arkansas, is the most active in the United States having a radioactivity of 90.5 x 10^{-10} gram of radium per liter (266 x 10^{-4} gram of uranium). Two springs at Arlington, Rhode Island, are next with activities of 58 and 47 x 10^{-10} gram of radium per liter. Dixon Spring No. 2 in this State is next with an activity of 29.3 x 10^{-10} gram of radium per liter. Several waters of high activity have been found in Germany and Switzerland. They are comparable with the highest waters in the United States. Other waters of Illinois vary in activity between that of Dixon Spring No. 2 and zero.

Several of the waters of Illinois have an activity as high as that of some waters for which medicinal value is claimed.

TABLE 6.—DECAY OF ACTIVITY OF WATER FROM DIXON SPRINGS, Nos. 2, 3, 4, & 7.

Time.	Activity (10^{-4} gram of Uranium).			
	No. 2	No. 3	No. 4	No. 7
1 hr.	2.58	2.80	2.05	....
2 hrs.	2.58	3.51	2.65	....
3 hrs.	2.68	....	2.73	30.4
5 hrs.	2.58	....	2.81	....
6 hrs.	....	3.25	2.81	....
18 hrs.	....	....	2.46	24.0
24 hrs.	2.27	2.80	2.05	23.0
2 days	1.79	....	....	17.6
3 days	....	1.55	1.31	....
4 days	1.26	....	....	11.4
6 days	0.82	1.24	.82	....
12 days	0.18	.43	.33	....
14 days	0.12	....	....	....
19 days	0.10	.33	.30	0 60

CONCLUSIONS

The activity of waters from deep-rock wells is low and constant.

The activity of waters from the drift is low, but varies with the calcium, magnesium, and residue.

The activity of waters from the lower Mississippian is low and there is no relation to the mineral content.

The activity of spring waters of the Ozark uplift is the highest in the State, and bears ho relation to the mineral content. Spring waters north of the Ozark uplift have a low and constant activity and closely resemble the waters of the deep-rock wells.

The activity of waters of Illinois bears no relation to the depth of the well.

The activity is due to radium emanation. In no case was uranium or thorium found.

The activity of Illinois waters is comparable with the activity of other waters of the United States and Europe.

The maximum activity observed in the waters of the State is exceeded within this country, but equals that of some waters for which medicinal value is claimed.

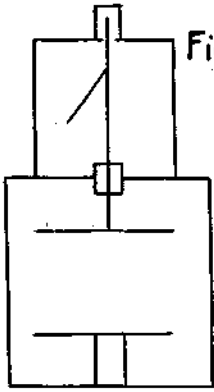
TABLE 7.—RADIOACTIVITY OF AMERICAN AND EUROPEAN WATERS.

	Electrostatic units x 10^{-3}	
Austria, Tyrols, Froy Magnesium Springs	51.0	(7)
Austria, Tyrols, Froy Iron Springs	11.0	
Austria, Tyrols, Froy Sulphur Springs	4.5	
Italy, Naples, Near Hassler Hotel	2.7	(39)
Italy, Naples, Appolo Water	1.5	
France, Voges, Bain les Bains	16.0	(29)
France, Vichy, Chomel Spring	4.6	
France, Bagnoles de l'Orne	3.3	
France, Luxeuil, Grand Bain	2.3	
Germany, Gastein	149.0	(39)
Germany, Baden Baden Buttquells	126.0	
Germany, Baden Baden Freidrichsquelle	6.7	
Germany, Karlsbad Eisenquells	47.0	
Germany, Karlsbad Felsenquelle	5.3	
Germany, Wildbad	1.8	(117)
Germany, Wiesbaden Koch Brunnen	2.3	(48)
Germany, Karlsbad Muhl Brunnen	31.5	(74)
Russia, Caucausus, Essentuky No. 6	8.6	(81)
Russia, Caucausus, Batalinsky	1.5	
Sweden, Uppsala Slottskallan	4.29	(112)
Sweden, Uppsala Bourbrum	3.77	
Sweden, Stockholm Birjerjarlsg No. 120	35.68	
Sweden, Medevi Hoghum	6.38	
Switzerland, St. Joachimstahl	185.0	(74)
Switzerland, Rothenbrunnen	0.81	(109)
Switzerland, Disentis	46.7	
Switzerland, Andeer	3.26	

	Uranium 10^{-4} gram.	Curries 10^{-10}	
Arkansas, Hot Springs, Imperial Springs	266.0	....	(18)
Arkansas, Hot Springs, Twin springs	65.4	....	
Arkansas, Hot Springs, Arsenic spring	23.9	....	
Indiana, Bloomington, city water	....	0.27	(91)
Indiana, Bloomington, University water	....	0.45	
Massachusetts, Williamstown, Sand spring	....	1.21	(111)
Massachusetts, Williamstown, Wampanoag	....	2.1	
Massachusetts, Williamstown, Rich spring	....	0.1	
Massachusetts, Williamstown, Sherman spring	....	0.4	
Massachusetts, Williamstown, Cold spring	....	0.1	
Missouri, Columbia, University well	1.68	....	(82)
Missouri, Sweet Springs, Sweet springs	23.7	....	
Missouri, Fayette, Boonlick springs	4.6	....	
Missouri, Kansas City, Lake spring	48.2	....	
New York, Saratoga, Emperor	....	0.70	(84)
New York, Saratoga, Crystal rock	....	8.80	
Ohio, Oxford	....	0.70	(91)

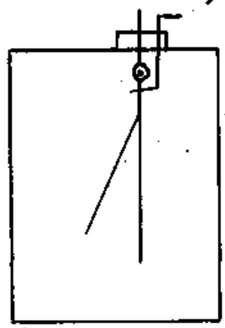
	Uranium 10^{-4} gram	Radium 10^{-10} gram	Electrostatic units 10^{-4}	
Rhode Island, Arlington, Spring	....	57.93	....	(89)
Rhode Island, Arlington, Spring	....	46.71	....	
Rhode Island, Providence	....	10.33		
Rhode Island, East Providence	....	1.18		
Yellowstone National Park				
Mammouth Hot Springs	37.9	14.4	26.3	(83)
Devil's Ink Pot	0.6	0.23	0.4	
Realgar Springs	10.6	4.0	7.4	
Nymph Springs	6.9	2.6	4.8	
Illinois				
Cairo	13.0	4.42	9.1	
Creal Springs, No. 3	24.6	8.36	17.2	
Dixon Springs, No. 2	86.1	29.27	60.2	
Dixon Springs, No. 7	67.0	22.78	46.6	
Homer Park	8.4	2.86	5.8	
Joliet, Well	11.4	3.88	8.0	
Mt. Vernon, Spring	5.2	1.76	3.6	
Sea Water	....	0.0003	....	(64)

Fig. 1.



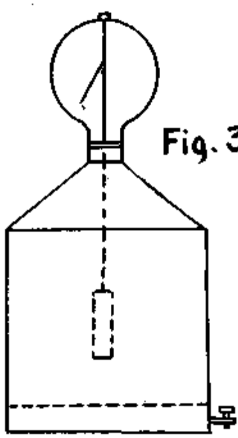
Simple Electroscope
For Solids

Fig. 2.



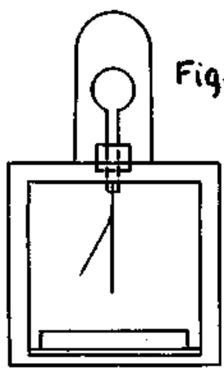
Simple Electroscope
For Gases

Fig. 3.



Simple Electroscope
For Solutions

Fig. 4.



Electroscope
For Solids

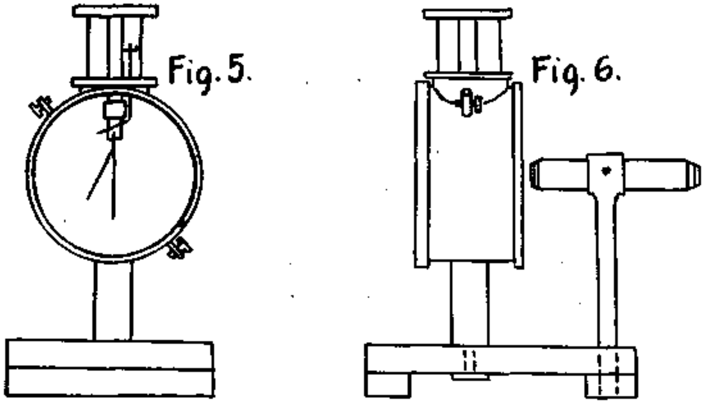


Fig. 5. Fig. 6.

Front View Side View

Electroscope for Gases

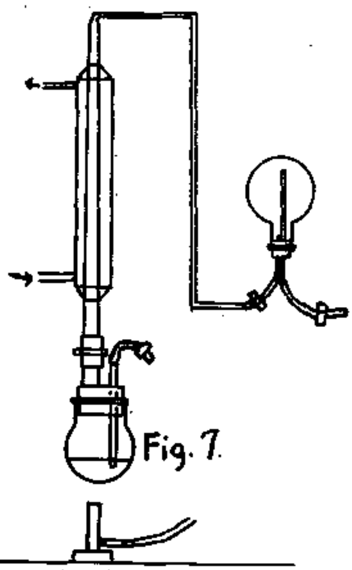


Fig. 7.

Apparatus for separating Emanation from Uraninite

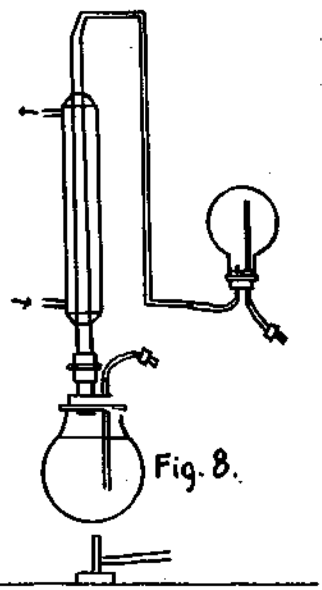


Fig. 8.

Apparatus for separating Emanation from Water

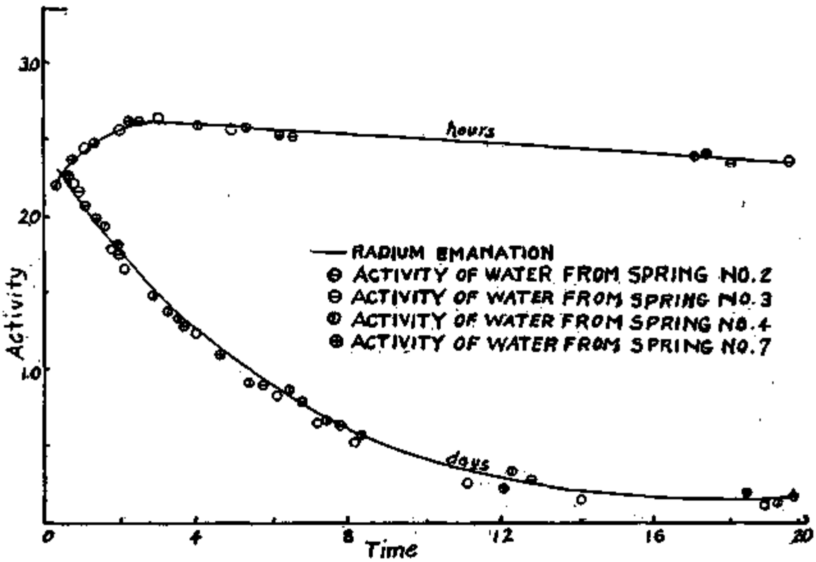


Plate 1. Comparison of decay of activities of waters from Dixon Springs with radium emanation.

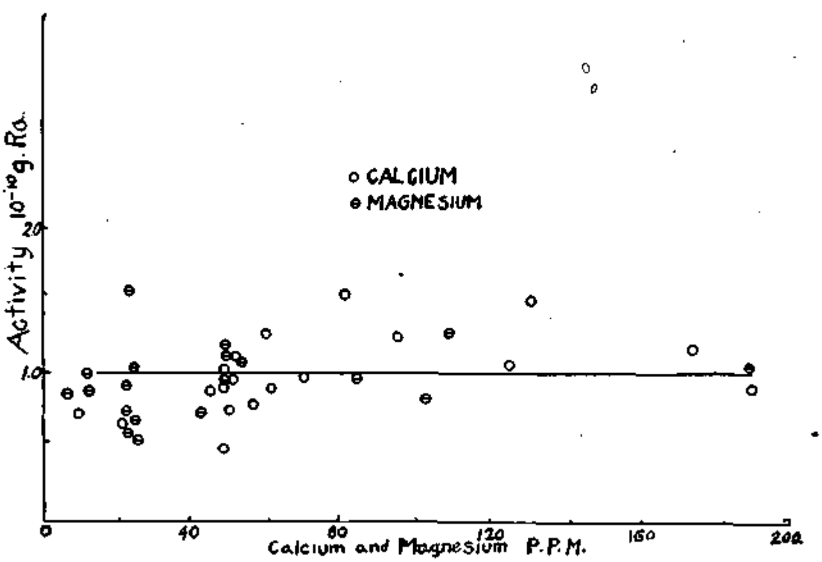


Plate 2.—Relation of activity to calcium and magnesium in waters from deep rock wells.

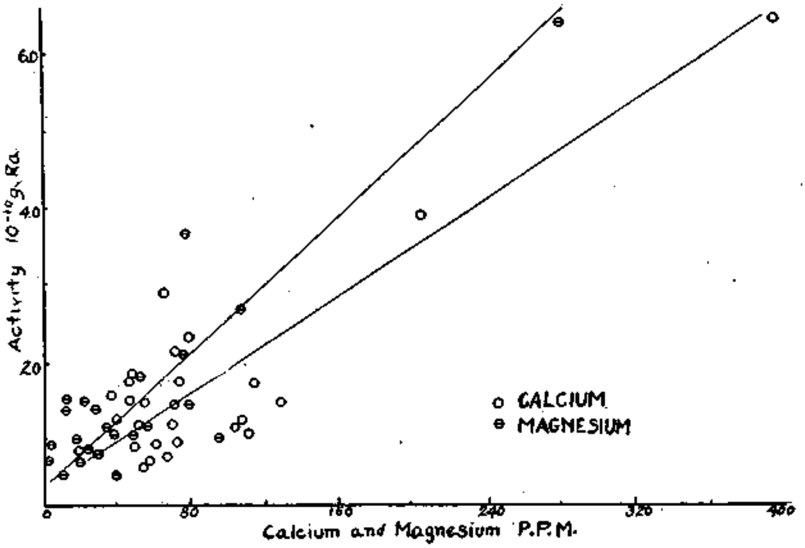


Plate 3.—Relation of activity to calcium and magnesium in water from drift wells.

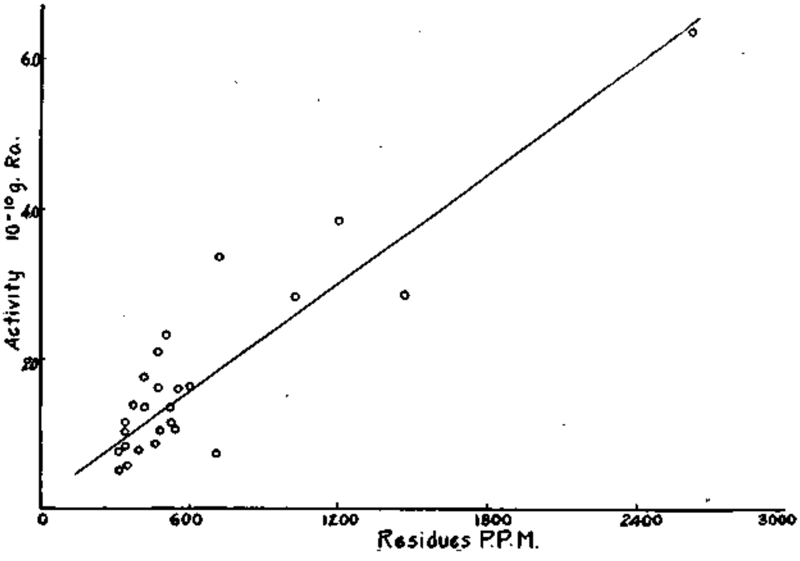


Plate 4.—Relation of activity to residue in water from drift wells.

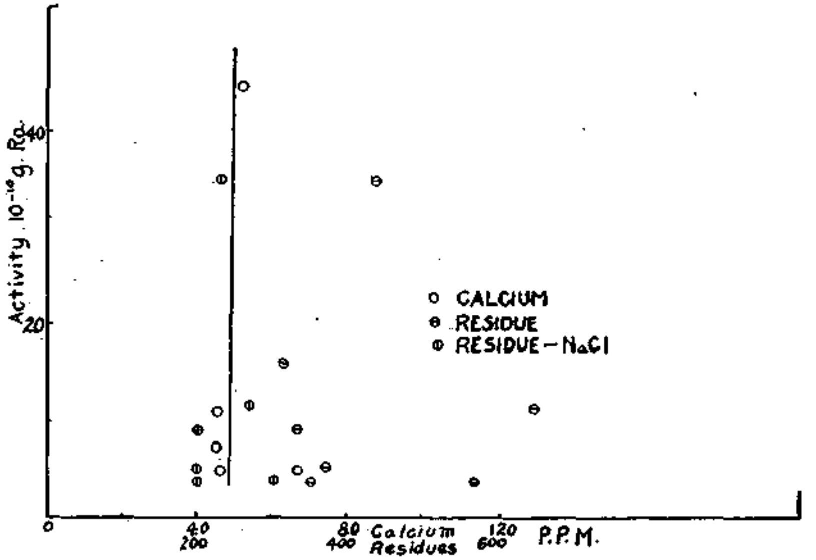


Plate 5.—Relation of activity to calcium and residue in water from lower Mississippiau.

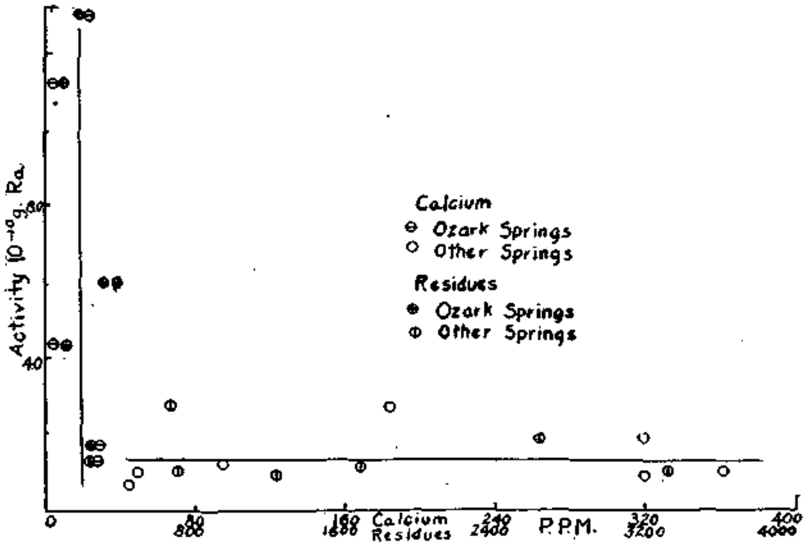


Plate 6.—Relation of activity to calcium and residue in water from springs.

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OPERATING RESULTS FROM THE NEW PURIFICATION PLANT AT QUINCY, ILL.

By W. R. Gelston.

A description of the new purification plant at Quincy, Illinois, was read at the 1915 meeting of this society, and the paper was published in the Proceedings of the American Water Works Association. It, therefore, does not seem necessary to discuss construction details at this time.

The plant was placed in operation in September, 1914, and the efficiency test was not completed until March 1, 1915. Since it is desirable in a report of this character to cover a period of an entire year, the writer has compiled the data given herewith for January and February from the report of the official test of the plant as submitted to the two interested companies by Mr. W. P. Langelier who conducted the test.

Table No. 1 shows by months the number of days upon which samples were plated: the average counts on standard agar plates

TABLE NO. 1.—BACTERIA IN QUINCY WATER. YEAR 1915.

Month	No. of test days	Average Agar count on				Average per cent of Colonies removed by		
		River	Settled	Filt'd	Treated	Sed.	Filt.	Hypo.
Jan.	30	10 488	1 617	202	80	85	98	99.2
Feb.	27	5 269	1 137	178	18	78	97	99.7
March	19	1 897	214	36	8	89	98	99.6
April	23	3 627	714	218	14	80	94	99.6
May	15	4 817	578	173	6	88	96	99.9
June	23	6 632	948	307	12	86	95	99.8
July	20	7 227	1 553	419	18	79	94	99.8
Aug.	14	3 171	851	323	25	73	90	99.2
Sept.	20	1 387	311	91	9	78	93	99.3
Oct.	22	549	123	23	9	78	96	98.3
Nov.	21	830	141	22	7	83	97	99.1
Dec.	23	840	139	28	6	83	97	99.3
Average	21	3 894	696	168	18	82	95.4	99.4

incubated 24 hours at 37 degrees, and the average percentage removal by sedimentation; by sedimentation and filtration, and by sedimentation, filtration and hypo treatment. The percent of removal by sedimentation and filtration shown from June to October inclusive, is somewhat low as compared with the other months. This is due to the fact that during a considerable portion of this period (about 85% of the time) the plant was operated with only one of the two sedimentation basins in service.

Table No. 2 shows the average monthly results of the tests for gas-forming bacteria. Lactose broth, incubated 48 hours at 37 degrees was the medium used. The figures shown for January and February are the average B Colli indices of the four waters tested regularly during the sixty days constituting the official test period, and they are taken from Mr. Langelier's report. The "B Coli index" method of reporting gas-former records was recommended in September, 1914, by a special committee of the New England Water Works Association. The writer should have used the same method, but found that, on the river and settled-water samples especially, 1/100 cc. quantities should have been tested regularly to give representative results, since a very high percent of the 1/10 cc. samples were positive. The average monthly percent of positive results on each of the various quantities of the four waters is therefore given, and in the column at the right the B Coli indices of hypo-treate,d water is shown. The average of the B Coli indices for the 12 months shown at the bottom of this column means that there were 81 B Coli present per liter of water as it was delivered to the mains. It should be noted, however, that Mr. Langelier did not mark his positive lactose broth tests as positive unless they were confirmed by transfers to lactose bile. He reported that 87 percent of the transfers made, confirmed the original lactose broth results, but that 50 percent of the tests not confirmed were from samples of hypo-treated Avater. It would, therefore, appear that the B Coli indices shown for the treated water beginning with the month of March are, at least, high enough.

On the ninth day of September a new intake pipe was placed in service. This pipe was laid because the supply obtained through the old intake was known to be somewhat contaminated by Quincy sewage.

TABLE NO. 2.—GAS FORMERS IN QUINCY WATER. YEAR 1915.

Month	Percent of positive tests in Lactose Broth								B. Coli index on treated
	River		Settled		Filtered		Treated		
	1cc.	0.1cc.	1cc.	0.1cc.	10cc.	1cc.	10cc.	1cc.	
Jan.									0.020
B. Coli Index		129		15.6		2.5		0.04	
Feb.									0.070
March	100	83	86		67	53	32	10	0.122
April	100	95	100			97	48	15	0.183
May	100	100	100	71		87	21	0	0.021
June	100	100	100	91		77	43	9	0.124
July	100	100	100	100		100	30	2	0.053
Aug.	100	100	100	72		94	44	9	0.125
Sept.	96	96	92	50		77	30	11	0.129
Oct.	100	41	80	15		25	14	5	0.059
Nov.	95	30	55	15	66	27	16	0	0.016
Dec.	100	35	83	13	94	15	27	2	0.045
Average	99.1	78	89.6	53	76	65.2	30.5	6.4	0.081

Table No. 2 shows a marked improvement in the B Coli content of the river, settled, and filtered waters, beginning with the month of September.

Table No. 3 shows the monthly average river stage and turbidity, color, and methyl orange alkalinity of both river and filtered water; the average percent of water used for filter washing, and the amount of alum and hypo used, stated in grains per gallon.

TABLE NO. 3.—SHOWING MONTHLY AVERAGE WATER CONDITIONS AND AMOUNTS OF ALUM AND HYPOCHLORITE USED. QUINCY. YEAR 1915.

Month	River stage	River turb.	Color		Alkalinity		% wash Water	Grains per gal.	
			River	Filt.	River	Filt.		Alum	Hypo
Jan.	3.89	29	25	6.4	167	142	2.5	3.17	.097
Feb.	10.19	97	28	5.9	110	87	2.3	3.16	.085
March	9.09	59	26	5.5	140	114	3.1	2.66	.057
April	9.55	47	30	5.0	131	109	4.4	2.40	.106
May	8.23	147	40	6.1	132	92	3.7	3.85	.116
June	12.44	382	44	8.5	126	81	1.7	5.39	.120
July	10.82	264	44	7.0	135	98	1.6	4.29	.134
Aug.	11.10	135	45	9.9	146	108	2.5	4.52	.170
Sept.	7.50	165	43	8.8	159	121	2.0	3.95	.202
Oct.	8.63	119	41	8.7	165	135	2.5	3.00	.153
Nov.	6.80	79	42	6.2	161	130	4.8	3.06	.145
Dec.	5.12	29	41	5.7	152	123	2.6	2.72	.104
Average	8.57	129	37	7.0	144	112	2.8	3.51	.124

The amount of wash water was estimated on a basis of fifteen thousand gallons per wash. A vertical rise through the sand, of thirteen to fourteen inches per minute was used. The allowance of fifteen thousand gallons per filter wash permits an average wash of four and one-half minutes, which is probably somewhat in excess of the average requirements. Air is also used for preliminary agitation of the sand.

Two periods of short filter runs, with a correspondingly high percent of wash water used, occurred during the year. The first which lasted longer began in March and ended in May. The second, of much shorter duration and more acute, occurred in November. Microscopic organisms were present in large numbers in the river water during both of these periods. A heavy dose of alum was necessary from June to September, both inclusive, partly because of the high turbidity, but more particularly because one of the sedimentation basins was out of service as above mentioned.

Tables No. 4 and 5 show the bacterial results on the river and hypo-treated water respectively, in the manner recommended by the committee of the New England Water Works Association.

Table No. 6 shows, by the same method, the turbidity of the river water and the color of the river and filtered waters.

TABLE NO. 4.—VARIATION IN NUMBERS OF BACTERIA IN RIVER WATER QUINCY, ILL. YEAR 1915.

Month	No. test days	Mean per cc.	Median per cc.	Variation in numbers. Number of test days: 100–:300	301–1000:	1001–10000:	10000–100000:	Gas Formers: No. of test days	0.1 cc. tests: total No.	No. Pos.	% Pos.	1 cc. tests: total No.	No. Pos.	% Pos
Jan.	30	10488	2850		2	22	6							
Feb.	27	5269	3000		6	16	5							
March	19	1897	1770		3	16		20	18	15	83	21	21	100
April	23	3627	2200		2	19	2	24	22	21	95	25	25	100
May	15	4817	3300			13	2	15	14	14	100	15	15	100
June	23	6632	2525		1	19	3	23	22	22	100	23	23	100
July	20	7227	6137			16	4	19	19	19	100	18	18	100
Aug.	14	3171	1850		1	12	1	18	18	18	100	18	18	100
Sept.	20	1387	1015		10	10		23	23	22	96	23	22	96
Oct.	21	549	555	4	16	1		22	22	9	41	22	22	100
Nov.	21	830	550		19	2		20	20	6	30	20	19	95
Dec.	22	840	228	14	4	4		23	23	8	35	23	23	100
Total	255	46734	25980	18	64	150	23	207	201	154	...	208	206	...
Aver.	...	3994	2165	..	..	...	..	...	...	...	78	...	...	99.1
% time	70	....	....	7.1	25.1	58.8	9.0	67.6	...	...	...	...	...	...

In connection with this report, mention should be made of the somewhat unusual operating conditions at Quincy. With continuous operation at the six million gallon per day rate there is a sedimentation period of four and one-half hours. As a matter of fact, the low service pumps were in operation only 2,679 hours during the year 1915. This is an average daily run of seven and one-third hours.

The pump house and filter plant force, which consists of one shift of men, broke the Fourth Commandment only nine times during the year, by operating the plant. It was broken eight times in January and February during the official test. This means that the nominal four and one-half hour period of sedimentation was lengthened to 14 hours on a considerable portion of the water and even to

TABLE NO. 5.—VARIATION IN NUMBERS OF BACTERIA IN HYPO TREATED WATER QUINCY, ILL. YEAR 1915.

Month	No. test days	Mean per cc.	Median per cc.	Variation in numbers number of test days: 0–10	11–25	26–50	51–100	101–250	Above 250	Gas formers: No. test days	1 cc. tests: Total No.	No. pos.	% pos.	10cc. tests: Total No.	No. pos.	% pos.
Jan.	30	80	11	15	8	2	1	1	3							
Feb.	27	18	12	13	2	1		2	9							
March	18	7.7	7	16	2					19	38	4	10	19	6	32
April	24	14	12	10	11	3				24	48	7	15	23	11	48
May	15	6	4	12	3					15	30	0	0	14	3	21
June	23	12	11	11	11	1				23	45	4	9	23	10	43
July	20	18	8.5	12	5	2		1		20	40	1	2.5	20	6	30
Aug.	17	25	12	4	10	2		1		17	34	3	9	16	7	44
Sept.	23	9	9	14	9					23	45	5	11	23	7	30
Oct.	22	9	9	16	5	1				22	44	2	5	22	3	14
Nov.	21	7	7	17	4					20	40	0	0	19	3	16
Dec.	23	6	4	21	2					23	46	1	2	22	6	27
Total	263	211.7	106.5	161	72	12	1	5	12	206	410	27	63.5	201	62	305
Aver.	...	17.6	8.9	...	..	..	..	..	..	...	...	..	6.4	...	..	30.5
% time	72	....	....	61.2	27.3	4.6	0.4	1.9	4.6	67.3	...	..	....	...	..	....

TABLE NO. 6.—TURBIDITY AND COLOR OF RIVER WATER AND COLOR OF FILTERED WATER QUINCY, ILL. YEAR 1915.

Month	No. test days	Mean turbidity	Turbidity—River water Variations: No. of test days							Color River Water						Color Filtered water				
			0–10	11–25	26–50	51–100	101–250	251–500	Above 500	No. test days	Mean color	Variations: No. T. Ds. 0–10	11–25	26–50	51–100	No. test days	Variations: No. T. Ds. Mean color	0–5	6–10	Above 10
Jan.	30	29	13	6	7	3	1			30	25		24	6		30	6.4	15	12	3
Feb.	27	97			8	16	7	1		27	28		9	18		28	5.9	15	13	
Mar.	18	59		4	10	1	3			18	26		14	4		18	5.5	10	8	
Apr.	20	46.5			15	5				18	30		8	10		19	5.0	13	6	
May	22	147				17	3	1	1	19	40			19		19	6.1	5	14	
June	24	382				3	12	6	3	21	44.4			21		22	8.5	0	20	2
July	26	204				1	16	7	2	24	44			24		25	7.0	0	25	
Aug.	23	135				2	21			23	44.5			23		23	9.9	0	22	1
Sept.	26	165				4	22			27	43.3			27		27	8.8	0	27	
Oct.	25	119				13	11	1		25	40.6			25		25	8.7	0	25	
Nov.	23	79			1	21	1			23	41.5			23		22	6.2	10	12	
Dec.	26	29	9	10	3	3	1			26	41			26		26	5.7	13	13	
Total	290	...	22	20	39	89	98	16	6	280	..		55	225		284	...	81	197	6
Aver.	..	129	..	..	..	..	..	..	..	...	37		..	..		..	7.0	..	...	..
% time	79	...	7.5	6.9	13.4	30.7	33.7	5.4	2.1	77	..		20	80		78	...	28.5	69.4	2.1

38 hours for the water standing in the basins from Saturday evening to Monday morning. On seven different occasions, continuous runs of 33 hours were made. On each of these runs samples were plated about six hours and about thirty hours after the beginning of the run. The results obtained from these tests are so contradictory that no conclusion can be drawn from them concerning the respective merits of continuous and intermittent operation.

Beginning about February 10th; liquid chlorine will be used at Quincy for final treatment. This change is being made on account of the present war price of bleaching powder. At the present price of the chlorine and hypo, the saving in cost of the sterilizing agent should be sufficient to pay for the liquid chlorine plant within one year.

The price of alum is also soaring. An attempt will be made to keep the coagulant cost down to a reasonable amount by using old Iron and Lime process, which made Quincy famous, in the first sedimentation basin and using alum, as at present, for the second basin. This plan can readily be followed without installing additional tanks or making extensive changes in the coagulant pipe system. The alum treatment after the iron and lime treatment, should eliminate all danger of incrustation in the sand beds, and it should also remove sufficient color to maintain a satisfactory appearance of the effluent. The price of the sulfate of iron has not advanced materially.

BACTERIAL PURIFICATION OP SEWAGE*

By Wilbur Fred Kamm

BACTERIAL PURIFICATION OF SEWAGE

Older methods of sewage disposal by dilution, intermittent sand-filtration, irrigation, contact beds, and sprinkling filters are all aeration processes; treatment by direct aeration in the presence of sludge is the latest development. In all cases the sewage must be brought into intimate contact with a sufficient quantity of fresh air; complete absorption must be insured; the sewage must be retained subject to bacterial action with an adequate air supply long enough to permit the completion of the process of purification.

Disposal of sewage by dilution is the cheapest if sanitary conditions are not interfered with. Disposal by irrigation is useful in dry climates and sandy soils in that the sewage serves both to fertilize and irrigate the soil.

The intermittent sand filtration method consists in delivering the sewage to a specially prepared field of sand for a certain period and then applying sewage to other similar fields, returning to the first after it has recovered from the former application. Crop production is not attempted. The sewage may or may not be treated by some preliminary process before application to the fields.

Disposal by contact beds consists in filling and emptying receptacles containing broken stone, gravel, cinders, etc.; the liquid is allowed to remain in contact with the bacterial slime which attaches to the surface of the granular material. After the discharge air is admitted to re-establish and provide for aerobic bacterial growth. A preliminary treatment to free the sewage from large particles is usually given.

The success of the sprinkling system depends upon the aeration obtained by spraying the sewage in a finely divided state into the air and then allowing it to trickle over crushed stone. This reduces the non-settling colloidal and dissolved organic matter to a point where the effluent will no longer putrefy.

*A thesis submitted in. partial fulfillment of the requirements for the degree of bachelor of science, June, 1916. The investigation was carried out under the direction of Professor Edward Bartow.

DISPOSAL OF SEWAGE BY AERATION

It has long been known that sewage exposed to air in thin sheets or permitted to trickle over rocks was partially nitrified and clarified; however, it was not until 1912 that promising results were obtained by experiments with direct aeration of sewage.

In Nov. 1912 Dr. Fowler, who had been impressed by the results obtained at Lawrence, Mass., by aeration of sewage in tanks containing slate, suggested to E. Ardern, M.S.C. and W. T. Lockett that they experiment with sewage disposal by means of aeration. Their first work showed that after aerating the sewage for a period of 5 weeks complete nitrification was produced. After settling, the effluent was drawn off and the process repeated until complete nitrification was attained in 6 hours. The accumulated sludge had a high nitrogen content and settled out readily. Aeration is now in use at Milwaukee with excellent results, in a two million-gallon plant.

In order to determine whether the oxidation of sewage during aeration was produced by the oxygen in the air alone in the presence of bacteria, or perhaps of some other organisms, Bobbins Bussell[5] made a study of the organisms present and isolated bacteria which changed ammonia to nitrite and to nitrate. We have repeated and extended Bussell's work.

SPECIAL APPARATUS AND MEDIA

Pure cultures of nitrifying bacteria were secured by means of special apparatus and special culture media. A modified "Beesley aeration apparatus"[0] was used (Fig. 1). By opening the stopcock a solution may be asceptically drawn from the flask through the tube (c) into the bulb (f) whence it may be run off through (d).

The media used were silica jelly[7] purified agar, and mineral agar.

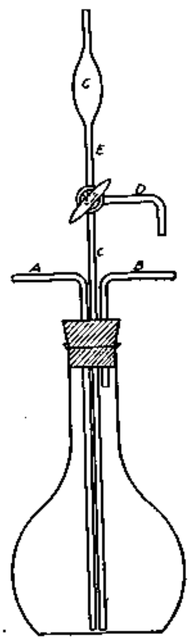


Figure 1.

ISOLATION OF BACTERIA

One aeration apparatus containing sterile ammonia broth and another containing nitrite broth were inoculated with 2 cc. of activated sludge. After nitrification had continued for several d 10 cc. from each flask was inoculated into similar fresh flasks. When this procedure had been repeated four times according to the "accumulation method of Beijerinck" fairly pure cultures should be obtained. After the last inoculation nitrification was permitted to go to completion. The nitrite broth required 18 days and the ammonia broth 20 days for complete oxidation (Fig. 2 and 3). After the 20th day the nitrite broth showed an increase in ammonia and nitrite, which was afterwards proven to be due to denitrifying bacteria. The ammonia broth showed but very slight denitrification. During the nitrification process, lasting 24 days, the bacteria decreased (Fig. 4 and 5) in both broths for about 15 days after which there was a gradual increase.

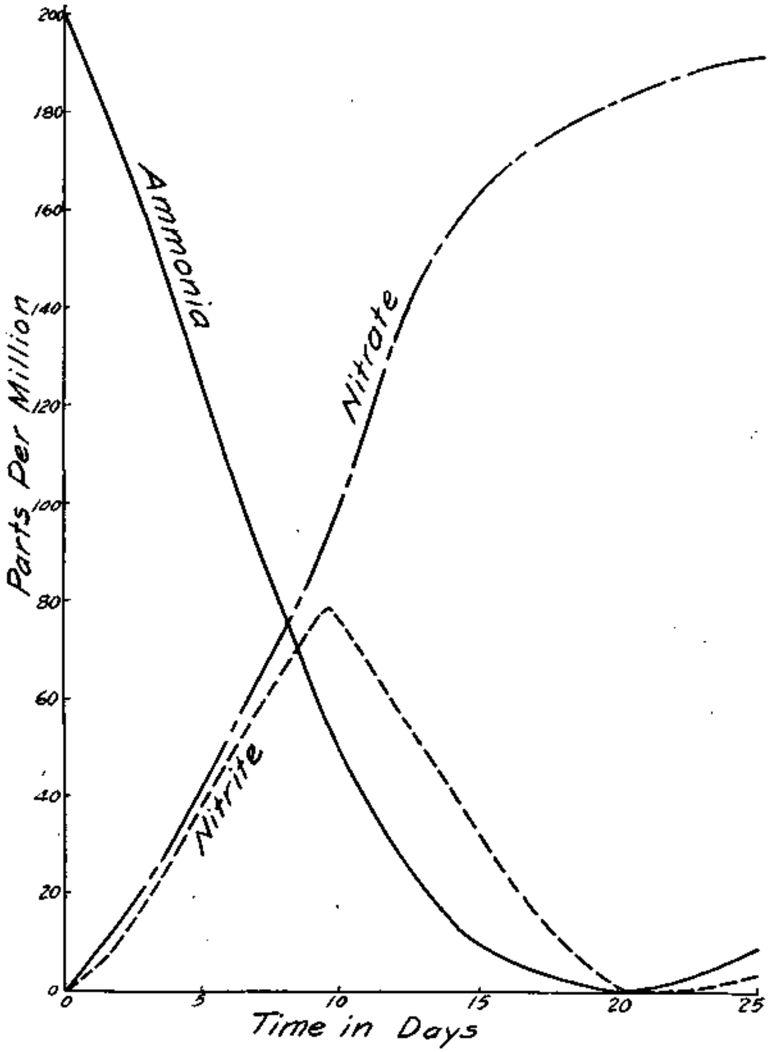


Figure 2.

After the lowest point in the bacterial reduction had been reached ammonia and nitrite silica jelly plates were inoculated, with ammonia and nitrate broths respectively. After 14 days, growth appeared on the ammonia silica jelly and five days later, growth appeared on the nitrite silica jelly. The nitrite organism was transferred to purified ammonia agar and the nitrate bacteria to purified nitrite agar.

From the two flasks after denitrification had set in, 8 different organisms Avere isolated. Of these, 6 proved to be denitrifying bacteria with the following group numbers,—

(1). 111.3313013 (3). 111.3333023 (5). 211.3333023
(2). 111.1333513 (4). 211.2333013 (6). 111.3331813

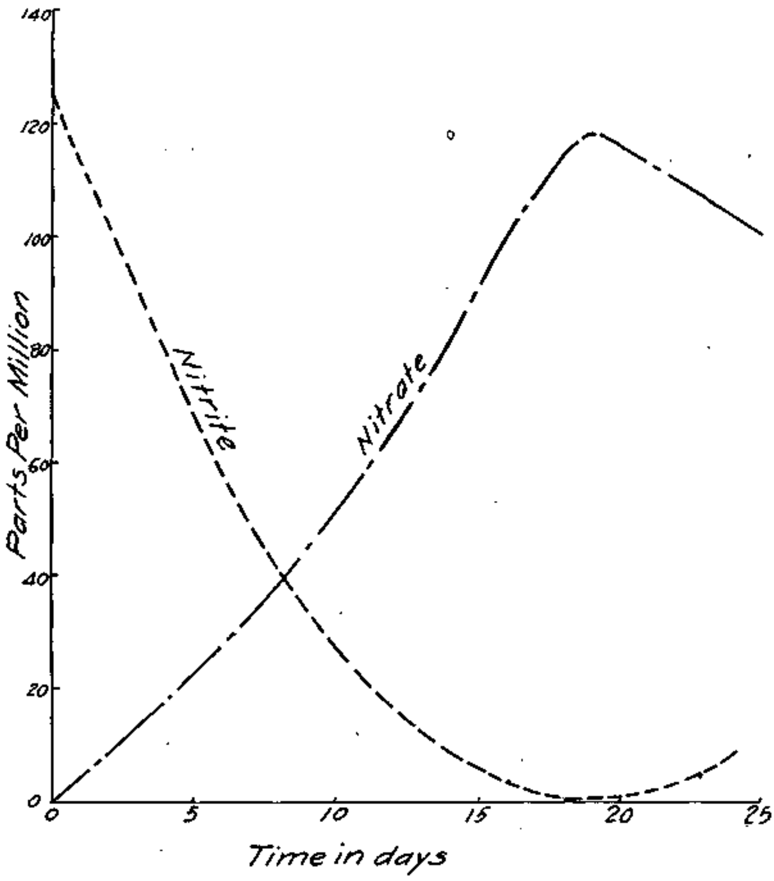


Figure 3.

From activated sludge nineteen organisms, typical activated sludge flora, were isolated upon standard agar and identified,—

(1). 111.2222012	(6). 111.3332023	(11). 112.3332013	(16). 122.3332823
(2). 111.2222022	(7). 111.3333513	(12). 121.1233011	(17). 212.1332513
(3). .111.2222033	(8). 112.2223022	(13). 121.2332512	(18). 211.3333813
(4). 111.2224012	(9). 112.2322013	(14). 121.2332913	(19). 222.1113022
(5). 111.2322022	(10). 112.2331013	(15). 122.2332523	

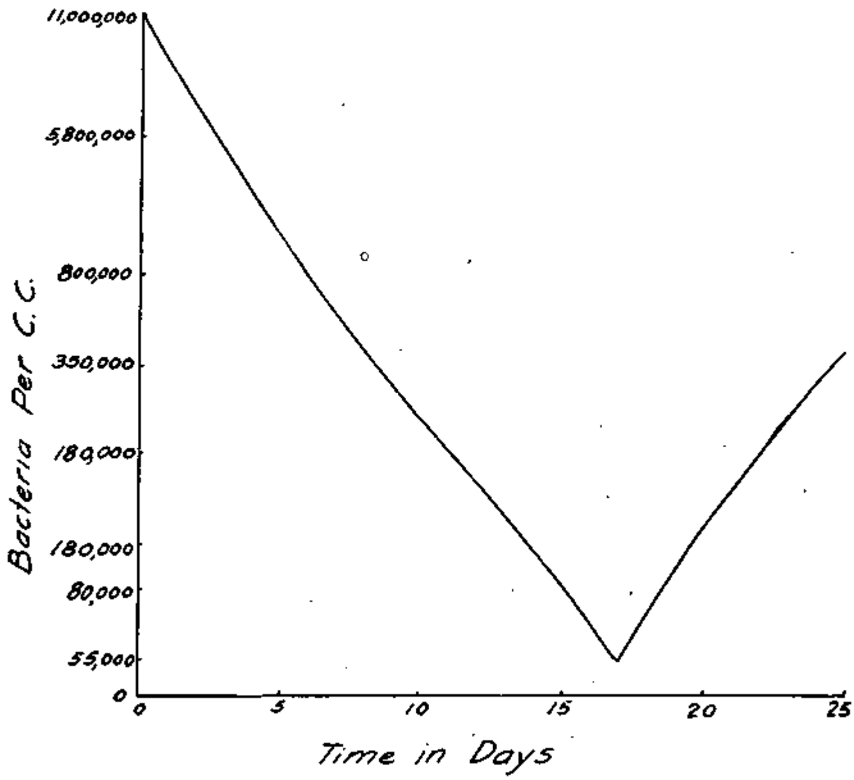


Figure 4.

EXPERIMENTS ON NITRIFICATION

The bacteria isolated from the mineral broths were nitrifiers. Four days after sterile ammonia broth had been inoculated with the nitrite bacteria and sterile nitrite broth with nitrate bacteria, the ammonia broth showed a very high nitrite content with traces of nitrate and the nitrite broth showed a great reduction in nitrite and a corresponding increase in nitrate. Experiments to determine the action of these nitrifying bacteria on sewage were undertaken.

ACTION OF BACTERIA ON STERILE SEWAGE

Fresh sewage obtained from the Champaign sewer was sterilized in 400 cc. portions in "Beesley aeration flasks" at 120° for 15 minutes on two consecutive days. Various combinations of bacteria were added to the sterile sewage.

Flask 1 sterile sewage + nitrite bacteria (Fig. 6).
" 2 " " + nitrate " (Fig. 7).
" 3 " " + nitrite + nitrate bacteria (Fig. 8).
" 4 " " as a blank or check (Fig. 9).
" 5 " " + 19 cultures + nitrite bacteria (Fig. 10).
" 6 " " + 19 " + nitrate bacteria (Fig. 11).
" 7 " " + 19 " + nitrite + nitrate bacteria (Fig. 12).
" 8 " " + 19 " (Fig. 13).
" 9 " " as a blank or check (Fig. 14).

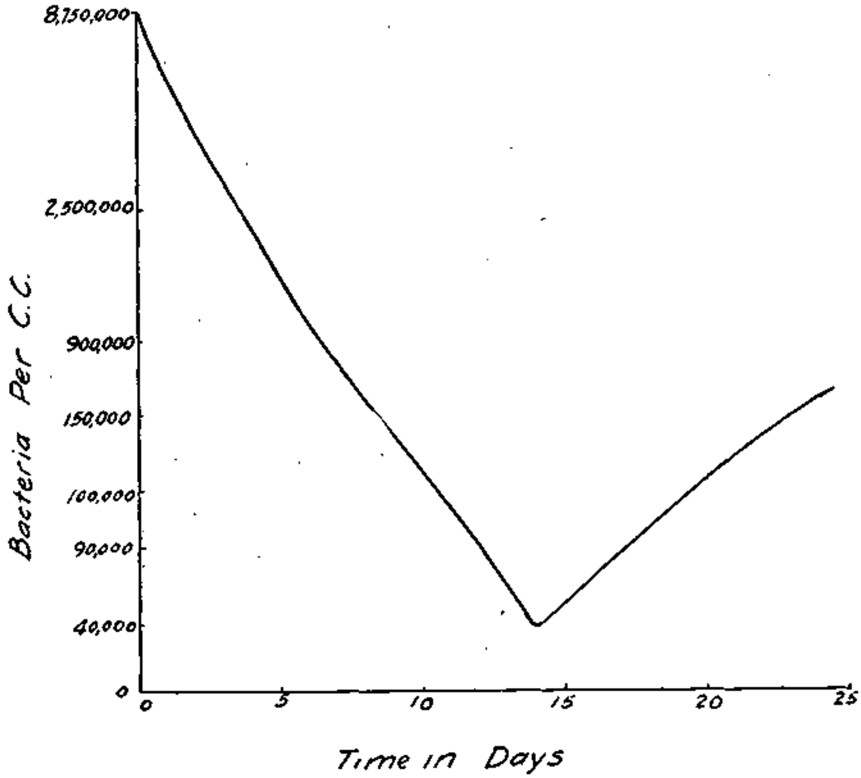


Figure 5.

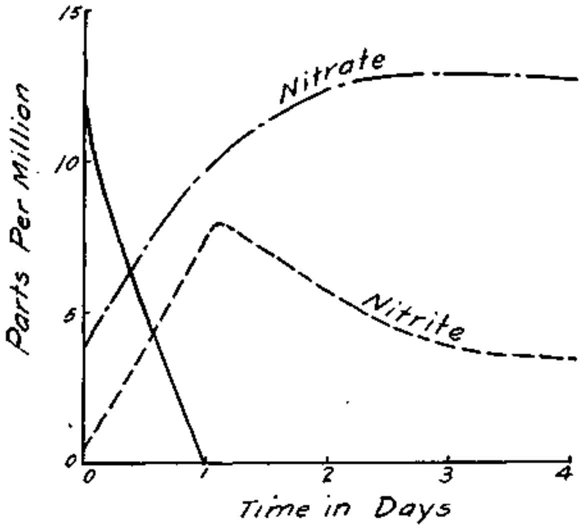
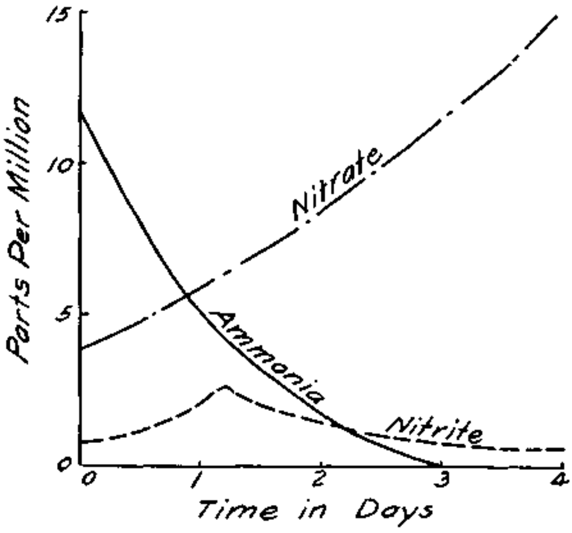


Figure 6.



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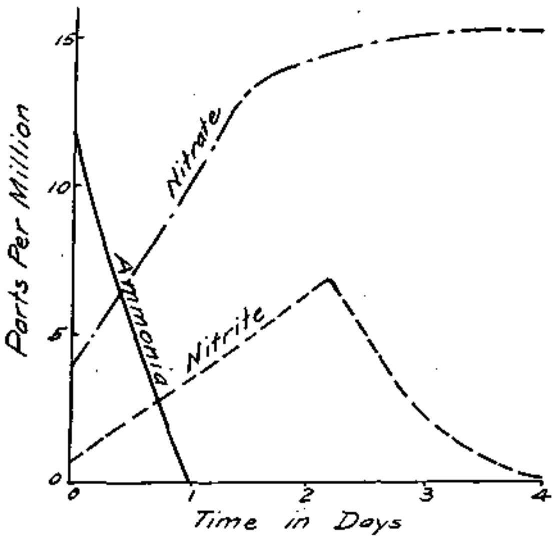

Figure 8.

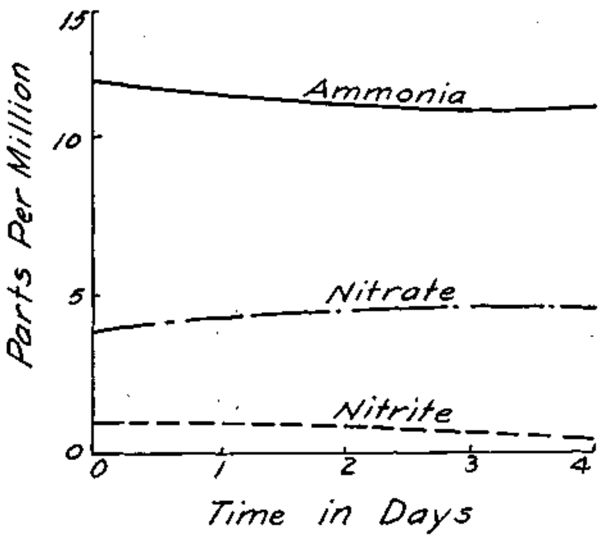

Figure 9.

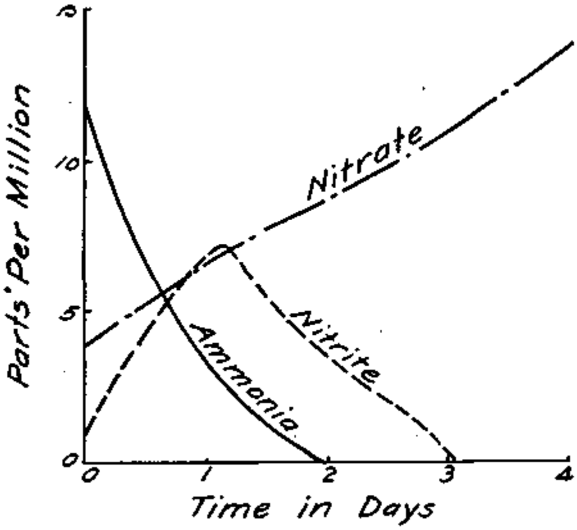

Figure 10.

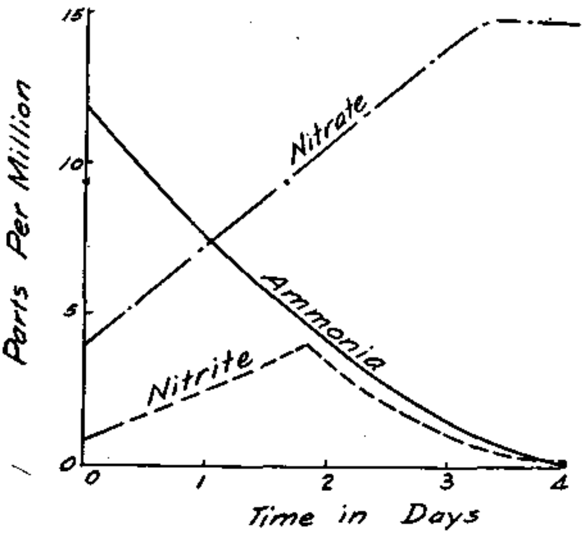

Figure 11.

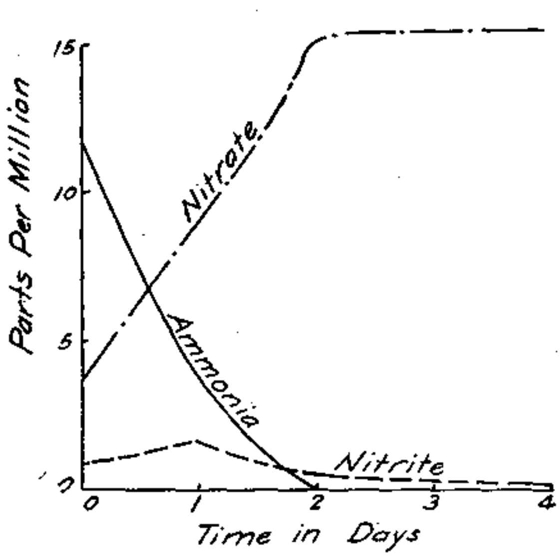

Figure 12.

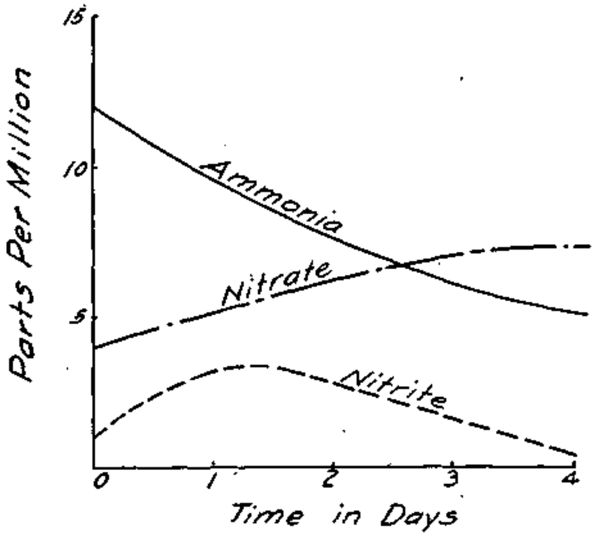

Figure 13.

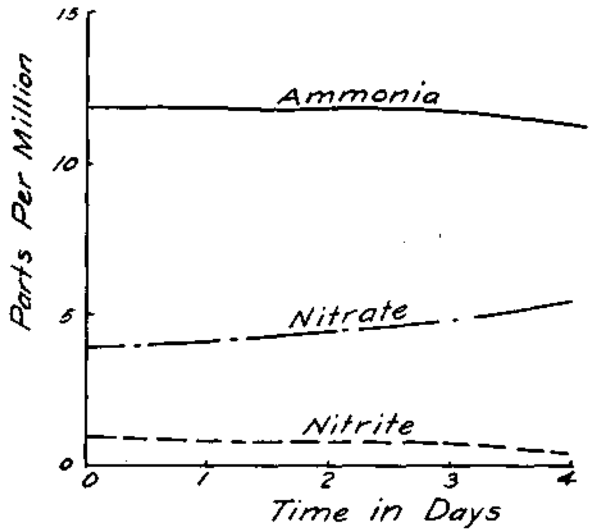

Figure 14.

Before inoculation the sterile sewage contained 12 parts per million of ammonia, 0.75 parts of nitrite and 4 parts of nitrate. The nitrite cultures in flask 1 which were supposed to change ammonia to nitrite also oxidized the nitrite to nitrate. In flask 2 the nitrate bacteria also oxidized the ammonia to nitrate. Because of the unexpected results the experiment was repeated twice later with similar results. A thorough examination of the cultures proved them to be pure.

Kaserer[9] claims to have isolated single nitrifying organisms which were able to oxidize ammonia to nitrate. He named the organism *B. nitrator.*

In flask 3 complete nitrification of both ammonia and nitrite was obtained.

Flask 4 containing sterile sewage as a blank, showed practically no oxidation.

Flask 5, containing cultures of nitrite, and the 19 other organisms showed complete oxidation after a period of 3 days.

In flasks 6 and 7 similar results as in flask 5 were obtained.

Flask 9 containing sterile sewage as a blank showed no nitrification.

The 19 cultures in flask 8 also showed a slight amount of nitrification, showing that probably weak nitrifiers were present.

CONCLUSIONS

a. The nitrification of sewage is produced by bacteria.

b. If sewage could be nitrified by pure cultures of nitrifiers alone on a commercial scale the sludge would be higher in nitrogen value because none would be lost through denitrification.

EXPERIMENTS ON DENITRIFICATION

As previously stated the ammonia and nitrite broths were completely nitrified and then showed a decrease in nitrate with a corresponding increase of nitrite and ammonia. From agar plates inoculated with broth eight different bacteria were isolated. Because of the denitrifying action which had been going on, the cultures were inoculated into sterile standard potassium nitrate broth in fermentation

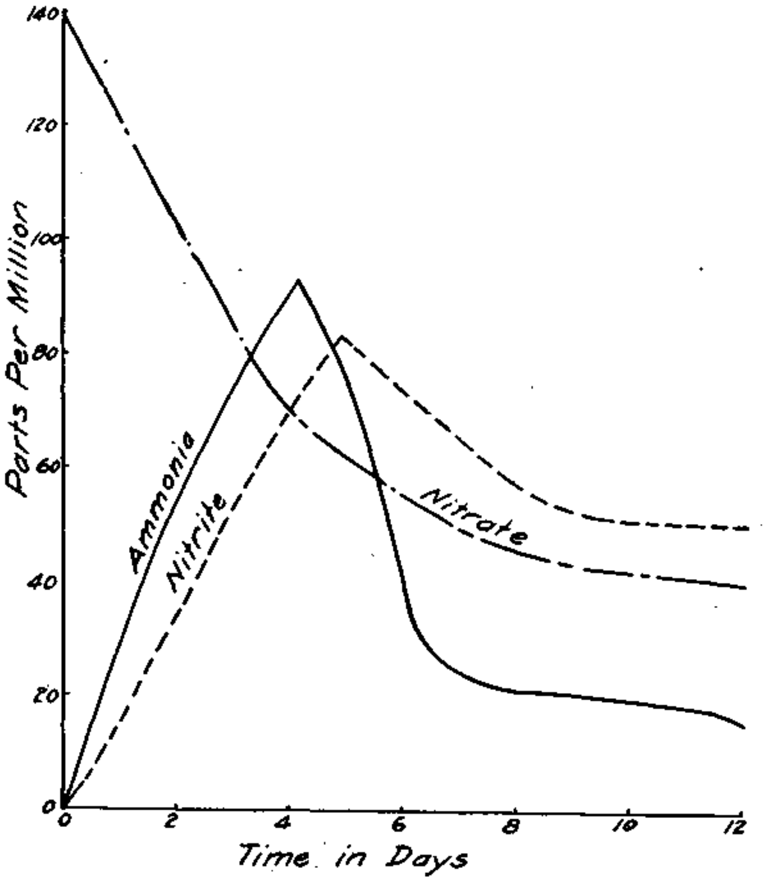

Figure 15a.

tubes. After four days the potassium nitrate broth was tested for nitrite and ammonia and six of the cultures proved to be denitrifiers.

In order to determine whether the six denitrifying organisms would denitrify under aerobic conditions, two flasks of sterile nitrate broth, (composed exactly like the nitrite and ammonia broth from which the cultures were isolated, except that instead of the sodium nitrite and ammonium sulfate equal amounts of sodium nitrate was substituted in both cases), were inoculated with a mixture of the 6 cultures; at the end of 7 days one of the flasks showed 5 parts per million of nitrate reduction and the other 6 parts. A blank or check showed no denitrification. Because of this slight amount of reduction it was readily seen that the organisms could not perform their function rapidly in a strictly mineral broth. Organic nitrate broths were prepared and inoculated.

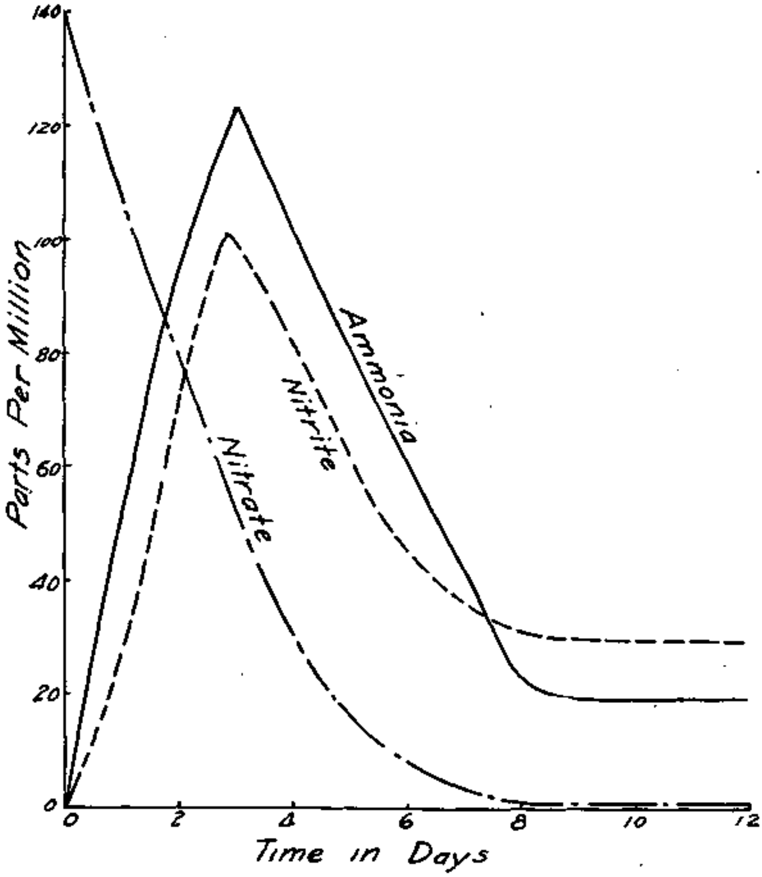

Figure 15b.

The presence of the organic matter in both cases enabled the bacteria to reduce the nitrate very rapidly. (Fig. 15a and 15b).

Similar experiments were carried out using the individual bacteria. The experiments were performed with aeration and with surface exposure. In the surface exposure experiments wide bottomed flasks stoppered with cotton plugs were used. In all cases reduction of nitrate to nitrite and ammonia resulted, however, the reduction in the aeration flask was twice as great as in the surface oxidation flasks.

DENITRIFICATION OF NITRIFIED SEWAGE

Nitrified sewage was taken from the University aeration tanks and sterilized at 120° for 15 minutes on two consecutive days. The nitrified sewage, in order that it should not be entirely free from sludge, was taken from the tanks 10 minutes after aeration had ceased. The sample thus obtained was well nitrified and contained a small amount of finely divided organic matter in suspension.

The sterile sewage contained 14 parts per million of nitrates, 1 part of nitrite, and 2 parts of ammonia. Two flasks of the sterile nitrified sewage were then inoculated with a mixture of the 6 denitrifying cultures and aerated. The cultures in both flasks of nitrified sewage produced almost identical results. At the end of 5 days the nitrate had decreased from 14 parts per million to 1 part. The ammonia increased from 2 parts to 4, while the nitrite increased from 1 part to 2 (see Fig. 16 and 17). At the beginning of the experiment

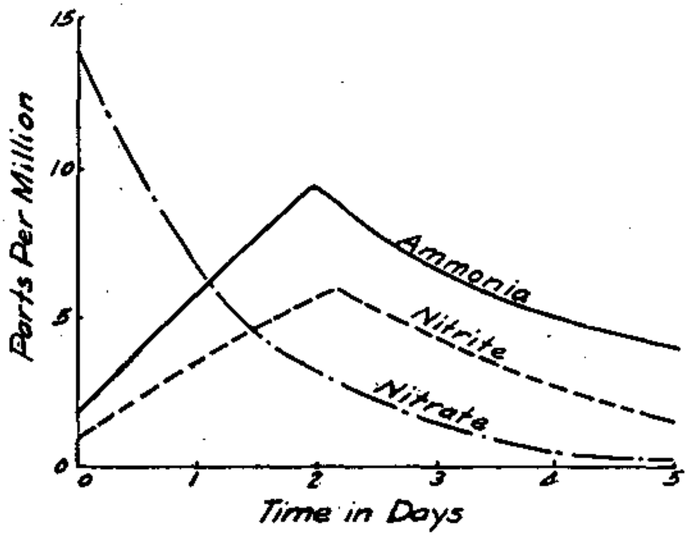

Figure 16.

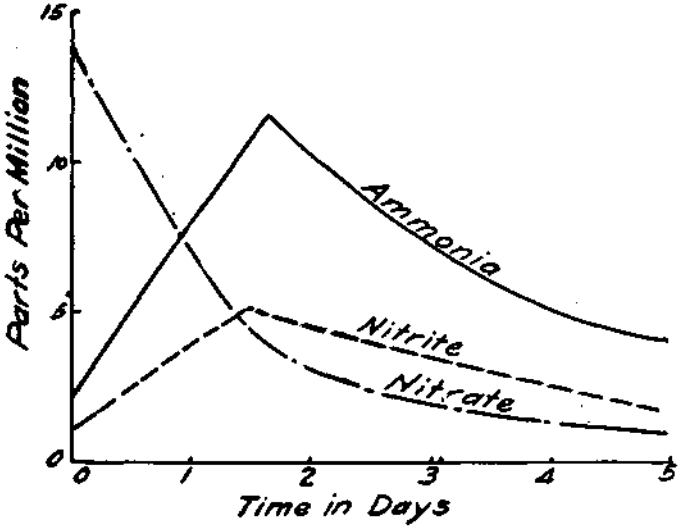

Figure 17.

the total amount of nitrogen present in the various forms amounted to 17 parts per million, while at the end of 5 days 7 parts remained. The form in which the loss of nitrogen resulted was not determined. The aeration flask containing sterile sewage as a blank or check showed no denitrification.

CONCLUSIONS

a. Denitrifying bacteria reduce the nitrate and nitrite in sewage.

b. They are constantly present in sewage, but their action is often overlooked because of the greater amount of nitrification.

c. In all the aeration experiments a large amount of nitrogen (as ammonia) is lost.

d. The denitrifying action (under certain conditions) predominates over the nitrifying action and may be the cause of the failure to nitrify the sewage in some aeration tanks.

e. Denitrifying organisms play an essential role in the purification of sewage by aeration in the presence of activated sludge.

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DECOMPOSITION PRODUCTS OF SEWAGE DISPOSAL*

By Frederick North Crawford

DECOMPOSITION PRODUCTS OF SEWAGE DISPOSAL

INTRODUCTION

Experiments by the Illinois State Water Survey in aerating sewage in the presence of activated sludge have shown that a stable effluent can be produced, which may safely be discharged into streams, and that the resulting sludge contains a high percentage of nitrogen available as a fertilizer.[1]

In order to gain a more complete knowledge of this process the effluent gases have been studied. During the fall of 1915 a similar investigation was carried on by W. D. Richardson, chief chemist Swift & Co. Chicago, † No systematic work had at that time been undertaken and only occasional analyses of the carbon-dioxide of the effluent had been made. ° It was considered that the increased carbon-dioxide in the effluent was due to moist combustion.

COLLECTING SAMPLES OF EFFLUENT GAS

The apparatus consists of an Erlenmeyer flask of 500 to 800 c.c. capacity fitted with a two-holed rubber stopper, through which glass tubes extended a short distance. A 6-inch glass funnel was attached to one of these tubes by means of a flexible rubber tube. To the other tube was attached a flexible rubber tube of somewhat greater length than the combined length of tube and funnel.

The Erlenmeyer flask was filled with the sewage and sludge, and the stopper inserted into the flask beneath the surface of the liquid. The flask was then inverted above the liquid leaving the funnel just beneath the surface in a part of the tank where the gas bubbles are abundant. As the gas rose through the funnel the other tube served as an outlet for the sewage and sludge. When the liquid in the flask was all displaced, its mouth was held below the surface of the liquid and the stopper replaced by another rubber stopper having two holes plugged with short glass rods.

*A thesis submitted in partial fulfillment of the requirements for the degree of master of science, June, 1916. The investigation was carried out under the direction of Professor Edward Bartow.

†Letter of Mr. W. D. Eichardson.

METHODS OF ANALYSIS

Carbon-dioxide was determined by the method of Hesse[2] adapted as follows:

1. Through one of the holes in the stopper enclosing the collected sample there were introduced 25 cubic centimeters of a solution containing 1.7 grams barium hydroxide and 20.1 grams barium chloride dissolved in one liter of distilled water, colored with phenolphthalein. One c.c. of this solution was equivalent to 0.1 cc. carbon-dioxide.

2. After complete absorption of the carbon-dioxide, which was accelerated by shaking, the excess of barium hydroxide was determined by titration with an oxalic acid solution containing 0.56325 grams per liter.

Oxygen was determined in the residual gas by transferring to a Hempel double absorption burette a definite volume which was then subjected to the action of alkaline pyrogallol. The method is accurate to 0.2, to 0.3 percent.

EXPERIMENTS

The air used in aerating the sludge was drawn from the university compressed air supply. Numerous analyses showed its composition to be normal, containing 4.3 parts of $C0_2$ per 10,000 and 20.5 percent oxygen.

During December 1915 while no fresh sewage was added to the activated sludge tanks the aeration of the old sewage was continued and at various times samples of gas were collected and the $C0_2$ determined.

The initial collections at irregular intervals over old sludge showed variations from 24.36 to 5.74 parts of carbon-dioxide per 10,000 by volume.

During January 1916, with an aeration period of 5 hours followed by a half hour sedimentation and a half hour for draining and refilling the tanks, four cycles were completed in 24 hours. Collection of samples was made during the aeration periods, beginning with the first bubbles through the filled tank, and 5 subsequent hourly samples were secured for each aeration period with these results:—

TABLE 1—CARBON-DIOXIDE CONTENT OF EFFLUENT AIR FROM JANUARY 6 TO MARCH 13, 1916.

Date.	Start.	Carbon-dioxide in parts per 10,000.					Air flow in cu. ft.	Temp. C Sewage.
		1 Hour.	2 Hours.	3 Hours.	4 Hours.	5 Hours.		
Jan. 6	14.2	....	....	....	....	8.7	161	16.1
Jan. 7	19.7	....	....	....	....	20.8	82	12.5
" 8	39.8	....	38.2	....	....	....	65	12.5
" 10	....	32.4	30.8	38.4	40.0	45.6	240	15
" 12	41.2	33.0	....	44.2	36.8	50.6	89	13
" 13	32.2	29.2	37.2	38.0	....	....	160	10.0
" 17	25.8	....	29.8	27.2	20.6	21.6	126	8.0
" 18	19.6	....	....	....	....	32.4	....	8.0
" 19	21.4	....	29.4	23.6	28.0	28.8	212	10.0
" 20	35.2	41.6	45.0	....	....	41.0	130	12.5
" 22	52.8	33.2	46.0	43.0	48.0	....	176	12
" 24	....	41.2	33.0	44.0	38.6	36.6	222	12
" 26	....	31.6	42.8	....	56.2	51.0	127	13.2
" 29	43.6	....	....	....	....	....	81	....
Feb. 1	....	....	....	38.1	34.5	33.6	....	11.0
" 3	42.6	39.5	40.8	40.7	41.6	41.9	....	11.0
" 4	37.1	36.6	33.9	37.1	38.8	37.6	....	12
" 8	41.3	38.3	37.0	38.3	43.5	42.2	....	11.0
" 9	47.8	45.7	42.4	47.7	....	....	....	11.5
" 10	45.4	45.4	46.3	49.4	50.7	....	....	11.5
" 11	35.1	....	....	....	....	....	....	....
Mar. 6	30.6	31.8	33.3	32.2	30.0	30.3	124	....
" 13	28.8	28.6	27.5	28.8	39.5	28.0	116	....
Average.....	39.67	37.5	36.41	38.02	38.94	39.42		

The average flow of air into 400 gal. sewage was 187 cu. ft. per hour at atm. pressure.

Discussion of Aeration Data:—During an aeration period when the tank was filled with sewage and no sludge, the CO_2 was highest at the beginning, dropping from 14.2 to 8.6 parts per 10,000. The second day, after the sludge had begun to build up, the CO_2 at the beginning and end were substantially the same, 19.7 and 20.8 parts per 10,000.

In each aeration period there was usually an initial drop in the effluent CO_2, followed by a marked increase, though the final amounts are not always the highest.

The rate of air flow has little or no relation to the amount of CO_2 in the effluent air. On Jan. 10 with an air flow of 240 cu. ft. per hour 45.6 parts of CO_2 per 10,000 were obtained; on Feb. 12 with an inflow of but 89 cu. ft. per hour, 50.6 parts per 10,000 were obtained.

When the effluent CO_2 had increased to 30 or more parts per 10,000 the oxygen was 1.0 to 1.2 percent lower in the effluent air than in the inflowing air. The effluent air contained from 19.2 percent to 19.9 percent of oxygen, thus about 5 percent of the oxygen was removed during its passage through the tank.

SOURCE OF CAEBON DIOXIDE

That the increase of carbon dioxide could not be due to simple oxidation without bacterial action is shown by the inhibition of sewage purification by excessive aeration in the earlier experiments at Urbana.

To determine whether carbon dioxide in the effluent gases was that held in solution by sewage, experiments were run with tap water and with sewage under conditions identical with those prevailing in the foregoing series of experiments, wherein sewage and activated sludge were aerated.

SUMMARY

In the three experiments with tap water, the general average of dissolved carbon-dioxide at the start was 22.8 parts per million; at the end of one hour, 14.1; at the end of two hours 6.4 parts per million, and then 0. When dissolved carbon-dioxide disappeared, alkalinity to phenolphthalein was at once evident, slowly increasing to 26 to 32 parts per million at the end of the 5 hour aeration periods. The total alkalinity remained nearly constant at about 350 parts per million. The effluent carbon-dioxide averaged 30 parts per 10,000 and fell steadily throughout aeration, though in but one experiment did it fall to the amount normally in the atmosphere. The oxygen content of the effluent air at the start of aeration was 19.6 percent but before the end of aeration it had risen to 20.6 percent, the amount normally in the atmosphere. The low oxygen at the start was probably due to the use of a drift well water containing iron.

TABLE NO. 2.—COMPOSITION OF THE EFFLUENT AIR FROM TAP WATER, SEWAGE, AND SEWAGE WITH ACTIVATED SLUDGE DURING AERATION.

Sewage alone.	Start	½ hr.	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	3½ hr.	4 hr.	4½ hr.	5 hr.
Dis CO_2	25		14		5.5		0		0		0
Phe. Alk.	0		0		0		13		33		32
M. O. Alk.	355		352		350		342		319		322
Eff. CO.	27.0	21.1	11.1	10.8	12.2	10.0	6.7	7.9	7.0	....	4.1
% eff. O.	20.0				20.65				20.6		20.6
Sewage without sludge											
Dis. CO_2	10.0		7.5		0		0		0		0 ppm.
Phe. Alk.	0		0		12		25		28		25 ppm.
M. O. Alk.	440		440		432		425		412		412 ppm.
Eff. CO_2	xxx		6.6		8.1		23.8		21.7		25.2 pp 10000
% eff. O.	....		....		20.0		19.9		19.7		19.7
Sewage with sludge											
Dis. CO_2	7.0		4.5		4.5		7.0		8.0		35 ppm.
Phe. Alk.	0		0		0		0		0		0 "
M. O. Alk.	398		394		....		390		391		400 "
Eff. CO_2	19.1		26.8		33.6		31		42		66.8 pp 10000
% eff. O	19.5		....		19.4		19.4		19.4		19.2

When sewage was aerated in the presence of the activated sludge the highest carbon-dioxide and the lowest oxygen recorded were obtained. The carbon-dioxide increased as the oxygen decreased. 1. Without sludge the dissolved carbon-dioxide disappears at the same time that it did in aerating tap water while in the presence of activated sludge it increased from beginning to end. 2. In the absence of activated sludge phenolphthalein alkalinity did not appear until the blowing had been in progress some time, as was the case with tap water. In the presence of activated sludge there was no phenolphthalein alkalinity at all. Methyl orange alkalinity, effluent carbon-dioxide and percent effluent oxygen in both cases are comparable. The aeration was continued 24 hours after the regular 5 hour aeration period was over. Where no activated sludge was present the phenolphthalein alkalinity fell to 2 ppm. and the methyl orange alkalinity fell to 325 ppm. In the presence of activated sludge dissolved carbon-dioxide fell to 4.5 ppm., but the methyl orange alkalinity remained constant.

The phenolphthalein alkalinity observed in the tanks, results from the breaking down of the acid carbonates in the water. According to titrations in the experiments the reduction of the half bound carbon-dioxide varied from 52 to 64 grams. According to the Law of Henry,[8] it is not completely expelled from the solution because the inflowing air contains carbon-dioxide.

CARBON-DIOXIDE FORMED BY BACTERIAL ACTION

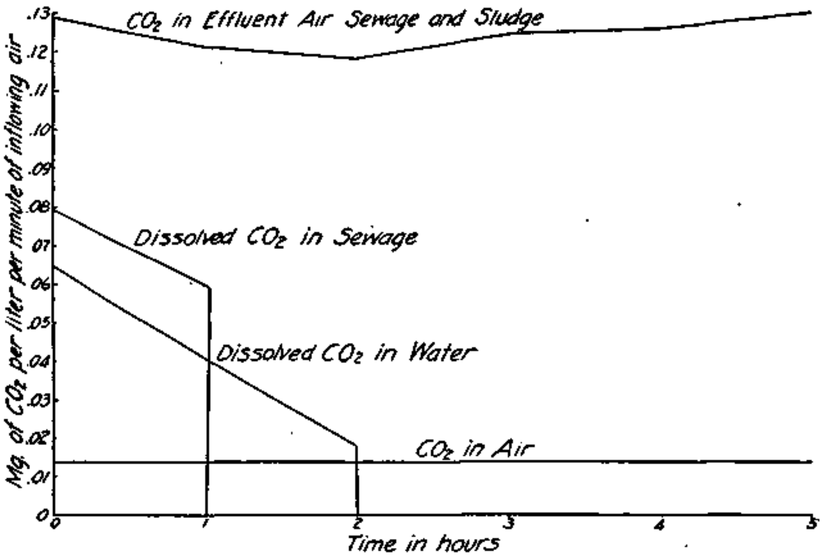
In order to determine the amount of carbon-dioxide formed by bacterial action fresh sewage was aerated under various conditions. When fresh sewage was added to a tank that had been in operation one week (see table 4), 125 grams of carbon-dioxide were blown out during the aeration period. The dissolved carbon-dioxide was 43 grams, leaving 82 grams of carbon-dioxide formed by bacterial action.

TABLE 4.—AERATION OF SEWAGE AFTER TANKS HAD BEEN IN OPERATION ONE WEEK, MARCH 6, 1916.

	Start.	1 hr.	2 hrs.	3 hrs.	4 hrs.	5 hrs.
CO_2 blown out	30.6	31.6	33.5	32.2	30.0	30.3
Dis. CO_2 ppm	12.	22.	23.5	21	14	14
M. O. alk. "	380	383	380	380	379	378
Phe. " "	0	0	0	0	0	0
% eff. O	19.4	19.2	19.4	19.4	19.5	19.7
Temp.	12 C.					12.5C
Air used	830 cu. ft. at atmospheric pressure.					

Similarly when sewage was added to a tank that had been in operation 4 days results comparable in every way with those obtained after a week's operation were obtained.

The rate of production of carbon dioxide under the three experimental conditions, calculated to milligrams of carbon dioxide per liter of air used in aeration find expression in the accompanying diagram, which illustrates well this phase of the role of biological fermentation in activated sludge treatment.



CONCLUSIONS

Aeration of tap water, of sewage and of sewage in the presence of activated sludge yields quantities of carbon dioxide and of oxygen which are greatly at variance.

1. Tap water containing bicarbonates, when aerated undergoes a loss of carbon dioxide, the partial conversion of bicarbonates to normal carbonates and the establishment of dissolved oxygen at the normal for water, saturated with atmospheric gases.

2. Sewage alone undergoes similar changes; the extinction of free carbon dioxide, partial conversion of bicarbonates to normal carbonates, and dissolved oxygen slightly less than the normal for air saturated water.

3. Sewage with activated sludge similarly aerated yields increasing quantities of carbon dioxide as the sludge builds up while the bicarbonate alkalinity remains unchanged.

The increment of carbon dioxide appearing in the effluent gases collected during aeration of sewage with activated sludge is derived from biological fermentation of carbonaceous matter.

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THE EFFECT OF GAS HOUSE WASTE ON THE BIOCHEMICAL OXIDATION OF SEWAGE*

By Chester William Lenzing

Because of the common use of phenol and its homologues as antiseptics and the adoption of phenol as the standard for disinfectants there has been attributed to wastes containing it an effect on biological purification of sewage disproportionate to the concentration. Waste liquors from gas house scrubbers contain varying amounts of phenols, thiocyanates, and other compounds, whose antisceptic action have been considered sufficient to inhibit bacterial growth, preventing nitrification (oxidation) and the production of a stable effluent.

HISTORICAL

Practically all of the investigation of the effect of the contamination of sewage by gas waste has been made in England although the first recorded work was done in Germany.

In 1877, H. Vohl reported a case of contamination of a well from a nearby gas works in Kreuznach, Germany. The proprietor of the well brought suit against the company, but lost because the chemists were unable to detect in the water compounds known to exist in the gas liquor. Vohl showed, however, that these compounds were changed in filtration through the soil and demonstrated that the water was contaminated by large quantities of ammonia, magnesia, nitrites, and thiosulphates.[14]

In 1907, Frankland and. Silvester,[4] studying the purification of a sewage containing as much as nine per cent of gas liquor in Oldbury, England, found that triple contact filters effected satisfactory purification. They found also that the vitality of B. coli was considerably reduced by one hundred parts thiocyanate per ten thousand in gas liquor.

In 1910 Ardern and Lockett,[1] working with gas liquor only, found that they could successfully oxidize solutions of phenol and thiocyanates on bacterial filters. They found that denitrification does not play an important role in the oxidation of thiocyanates. Phenol was more readily oxidized than the thiocyanates.

*A thesis submitted in partial fulfillment of the requirements for the degree of bachelor of science, June, 1916. The investigation twas carried, out under the direction of Professor Edward Bartow.

Fowler[3] in 1910 pointed out that sewage without gas liquor was oxidized weeks before that containing a small per cent of crude gas liquor. He isolated an organism from a bacterial filter which actually oxidized weak solutions of phenol.

In 1912 Ardern and Lockett[2] continuing their work with gas liquor, studying its effect on the oxidation of sewage, showed that one per cent of Manchester gas waste had a retarding effect on the oxidation of sewage by aeration, but noticed no effect on fine grained sand filters. The permanganate absorption figure remains higher as the filter matures, but the sewage is oxidized.

The purification of gas house waste was investigated at the Massachusetts Experiment Station at Lawrence.[11] It was found that treatment with chemicals such as lime, copperas, etc., and filtration through coke was a suitable treatment. No mention is made of the effect of the waste on the oxidation of sewage.

It is difficult to measure the effect of gas house waste on the biochemical oxidation of sewage. The oxygen consumed by the sewage is increased by such waste; the end-point of the methylene blue reaction is obscured by high color of the waste; the Lederer saltpeter method is applied in the following experiments to establish the difference in oxygen demand of the sewage with and without the addition of gas house waste.

This method of determining the biochemical oxygen demand involves the addition of a definite quantity of saltpeter to the sewage; incubation for 10 days at 20°C.; and determination of residual nitrate and nitrite nitrogen. The oxygen demand is the difference between initial and residual oxygen. One part of nitrate nitrogen by weight is equivalent to 2.85 parts oxygen; and one part nitrite nitrogen represents 1.7 parts available oxygen by weight.

EXPERIMENTAL

The sewage used was taken from the main Champaign sewer at the experimental activated sludge plant in the power house of the University, where the entire flow from the city (about 1 million gallons per day), passes on its way to Salt Fork. The gas liquor used was from condensers and scrubbers of the Champaign gas works; both coal and water gas, principally the latter, are manufactured at the plant.

Champaign sewage varies in composition from day to day and even from hour to hour. The usual difficulty was experienced in determining its average composition. The sewage is strongest at nine in the morning, at which time most of the samples used were collected. An analysis of a nine o'clock sewage made September 29, 1915, is typical.

TABLE I

Analysis of nine o'clock sewage collected Sept. 29, 1915

	Pts. per million
Total residue on evaporation	2145
Oxygen consumed	94
Ammonia nitrogen	40
Albuminoid nitrogen	24
Total organic nitrogen	24
Nitrite nitrogen	0
Nitrate nitrogen	1.6
Alkalinity (as $CaCO_3$) methyl orange	608.
Alkalinity (as $CaCO_3$) phenolphthalein	48.
Chlorine	142.

The composition of the waste liquor obtained October 21, 1915, is shown in Table II.

TABLE II

Analysis of the crude unsettled gas liquor

	Pts. per million
Residue on evaporation	2006
Suspended matter	1466
Alkalinity (as $CaCO_3$) methyl orange	468
Total organic nitrogen	43.4
Nitrite nitrogen	0
Nitrate nitrogen	0

TABLE III

Analysis of the unsettled waste

	Pts. per million
Residue on evaporation	780
Suspended matter	258
Alkalinity	464
Total organic nitrogen	64
Nitrite nitrogen	0
Nitrate nitrogen	0

In order to check the strength of the gas liquor from day to day, establishing the validity of the experiments, the ammonia and thiocyanate content were determined according to standard methods, and the phenol content was determined by the methods of Skirrow[13] which was found accurate within 0.5%. Phenol in two samples of liquor collected at different times was found to be 213 and 433 parts per million respectively.

Analysis of the waste showed it to be alkaline, which Lederer has shown to be a condition essential to the successful application of his method. The reagent is a solution, containing 26.66 grams C.P. sodium nitrate in 1 liter, 1 c.c. of which added to 250 c.c. of sewage represents 50 ppm. available oxygen.

. . Sewage was introduced into selected 250 cc. bottles from an aspirator bottle provided with a stirring device (a spiral wire) to keep solid particles evenly distributed in the sewage. Due precautions were taken to prevent artificial aeration. The samples were incubated from 1 to 10 days at 20°C. Each day one bottle was withdrawn for the determination of nitrate nitrogen by direct nesslerization after reduction with aluminum foil, and of nitrite nitrogen by the colormetric method.

Because of irregularities in manipulation, the first series was rejected. In the second series, of 5 sets of 15 bottles each, sets 1, 2, 3, and 4 contained respectively 400, 450, 500 and 500 ppm. available oxygen; set 5, 500 ppm. available oxygen and 10% of crude gas-house waste. The quantity of available oxygen was in large excess. The results are shown in Table 1.

TABLE 1.—COMPARISON OF THE OXYGEN DEMAND OF SEWAGE WITH AND WITHOUT GAS LIQUOR. SERIES 2.

Days Incubation	400 ppm O Set 1	450 ppm O Set 2	500 ppm O Set 3	10% gas waste 500 ppm O Set 4	Set 5
.5	186	238	263	258	218
1.0	186	241	261	227	216
1.5	195	245	190	187	188
2.0	195	245	281	189	188
2.5	195	245	124	129	55
3.0	138	245	238	248	159
3.5	229	257	227	237	113
4.0	125	177	227	233	205
4.5	125	253	404	304	242
5.0	273	344	349	326	244
6.0	273	322	372	340	250
7.0	296	348	341	340	330
8.0	325	371	328	310	250
9.0	267	281	304	286	233
10.0	278	253	269	304	lost.

Our conclusion, from the second series, by comparison of sets 2, 3, 4, with set 5 of series 2, is that the presence of 10 per cent gas waste in sewage has no greater effect on the biochemical oxygen demand than the possible error in analysis. With care the experimental error can be reduced to 10 per cent but with the large quantities of residual nitrate and nitrite nitrogen, it is likely that the error runs above 10 per cent.

In order to eliminate the possible source of error due to excessive residual nitrate, less sodium nitrate (equivalent to only 150 ppm. oxygen) was added to the bottles to be incubated for one day, and the amount of oxygen was increased by successive steps of 50 ppm. in bottles to be examined for the four succeeding days. (Table 2).

TABLE 2.—COMPARISON OF THE OXYGEN DEMAND OF SEWAGE WITH AND WITHOUT GAS LIQUOR, SERIES 3.

Days Incubation	Available O added.	Residual O from NO_2		Residual O from NO_3		Oxygen demand	
		Parts per million					
		Sets* 1 & 2	Sets** 3 & 4	Sets* 1 & 2	Sets** 3 & 4	Sets* 1 & 2	Sets** 3 & 4
1	150	17	1.8	67	110	66	25
2	200	32	93	73	0	105	106
3	250	32	127	105	0	113	120
4	250	25	144	79	0	140	110
5	300	34	153	136	0	130	117
6	350	23	114	204	96	132	140
7	350	14	116	206	104	130	151
8	350	16	93	183	147	150	132
9	350	20	122	174	112	152	125
10	350	15	170	182	34	157	146

*No gas liquor.
**10% gas liquor.

The results obtained were more satisfactory, but the gas liquor still showed practically no interference.

The difference in residual nitrite nitrogen (Table 3) was very marked and difficult of explanation. The gas liquor may slow up the reaction in such a way that the nitrate is reduced only to nitrite. It may be that the gas liquor inhibits the action of some of the bacterial forms which denitrify from nitrite to ammonia or free nitrogen.

TABLE 3.—RESIDUAL NITRITE NITROGEN FROM SERIES 3.

Days incubation	No gas waste	10% waste
1	10	1
2	18	55
3	19	75
4	15	85
5	20	90
6	13	68
7	8	70
8	10	55
9	12	75
10	9	100

Another series in which 15% gas house waste was used showed no increment of biochemical oxygen demand and no interference with biological action.

Experiments with sodium nitrate and 15% gasliquor in the absence of bacteria (in sterile water) gave negative results. The liquor itself was sterile, as was shown by negative growth on agar plates 24 hours at 27°C.

To each of 4 bottles of sewage containing 0.5%, 10%, and 15% of gas liquor 350 parts per million of oxygen in sodium nitrate were added and then incubated at 20°C. The number of bacteria growing on agar at 37°C was determined at 24 hour intervals; instead of the anticipated decrease, there was an increase in the bacterial count from day to day. These results were confirmed.

TABLE 4.—BACTERIAL COUNTS ON AGAR MADE FROM SEWAGE WITH AND WITHOUT GAS HOUSE WASTE.

Percent of gas liquor	3 hrs.	1 day	3 days.	8 days.
0	850,000	1,700,000	400,000	200,000
5	1,500,000	1,200,000	1,200,000	no count
10	1,200,000	1,900,000	2,500,000	24,000,000
15	280,000	1,700,000	2,600,000	44,000,000

1. By use of the saltpeter method for determining the biochemical oxygen demand, with its large possible experimental errors, no effect was noticed on the biochemical oxidation of sewage by 10 and even 15 per cent of the gas waste.

2. The presence of the gas waste in sewage containing sodium nitrate has the effect of increasing the nitrite nitrogen after incubation, over that of sewage containing no gas waste.

3. That 15 per cent of the gas house waste has no inhibiting action on the number of bacteria as shown by counts made on agar incubated at 37 degrees. An increase in the number of bacteria was observed in sewage containing gas waste over sewage containing no gas waste.

4. Determinations of ammonia nitrogen and thiocyanate were found sufficient tests for comparing waste at one time against waste at another.

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ASSOCIATIONS AND COMMISSIONS

Certain phases of Illinois water problems are of interest to several state, interstate, national, and international associations and commissions, which have been cooperating as far as possible in order to prevent duplication of work. In order to place before the citizens interested in the water supplies of the State information concerning the activity of these associations, it has been customary to publish a list of the organizations with abstracts of articles pertaining to the water supplies of Illinois. The organizations are noted below. References to articles regarding water, water supplies, sewage disposal and other subjects of interest to waterworks men published by these organizations during 1916 are also given. An attempt has been made to make the list complete but there are possibly some articles which may have been overlooked.

ILLINOIS STATE BOARD OF HEALTH

Established in 1877. John A. Robinson, M. D., Chicago, president; -C. St. Clair Drake, M. D., Springfield, secretary and executive officer. By mutual consent the care of the water supplies of the state is in the hands of the State Water Survey. Water analyses have been made for the State Board of Health when requested. The State Board of Health and the State Water Survey have cooperated in the investigation of several typhoid-fever epidemics.

The State Board of Health began the publication of Illinois Health News in 1915. In Volume II are the following articles.

Typhoid fever at Tuscola, p. 143.

Hansen, Paul.—(1) Disposal of sewage from country houses, small institutions and country clubs, p. 151. (2) Water supply and sewerage, p. 259.

ILLINOIS STATE GEOLOGICAL SURVEY

Established in 1905. F. W. DeWolf, University of Illinois, Urbana, director. The State Geological Survey has charge of drainage investigations and is interested in the character of the water obtained from deep wells and the horizons from which the water can be obtained.

STATE LABORATORY OF NATURAL HISTORY

Established in 1884. Professor S. A. Forbes, University of Illinois, Urbana, director. The State Laboratory of Natural History is interested in the character of the streams of the State with respect to their effect on aquatic life. A special study is being made to determine the effect of Chicago sewage on the plankton and food fishes in Illinois River, the chemical work of which has been done under the direction of the State Water Survey.

STATE PUBLIC UTILITIES COMMISSION OF ILLINOIS

Established in 1913. William L. O'Connell, 714 Insurance Exchange Bldg., Chicago, chairman. The commission, as an administrative body, has jurisdiction over all private corporations and individuals who own or operate water or power plants as public utilities. Its powers do not extend to municipally owned plants. It has extensive authority over reports, accounts, capitalization, mergers, intercorporate contracts, rates, services, and facilities. A certificate of convenience and necessity from the commission is necessary to authorize a new enterprise as a public utility, and the operation of the undertaking is brought under its active control and regulation. Under the present law a public utility must be incorporated by the Secretary of State, before receiving a certificate of convenience and necessity from the Utilities Commission. No fees are charged by the commission in any action, except authorization of security issues. Much of the commission's work consists of the adjudication of complaints concerning the practices of public utilities.

RIVERS AND LAKES COMMISSION

Established in 1909. A. W. Charles, Carmi, chairman; Leroy K. Sherman, Chicago, and Thomas J. Healy, Chicago, members; Charles Christmann, State Bldg., Chicago, secretary.

The annual report for 1916 tells of the action in numerous complaints, made to the Commission and reports on surveys of Pecatonica River, Galena River,, Galena Flood, Illinois River, Kankakee River, La Moihe River, Spring-Lake drainage and levee district and Big Muddy River. It also includes reports of the improvement of the levees at Cairo, Mound City, and Shawneetown.

Report of Survey and Investigation of the La Moine River with reference to flood control and navigation, by John B. Fountain. Bull. 17.

Flood Control for Pecatonica River. Bull. 18.

UNITED STATES PUBLIC HEALTH SERVICE

Dr. Rupert Blue, Washington, D. C, Surgeon-General. The Public Health Service publishes bulletins and a weekly journal entitled "Public Health Reports," containing current information regarding the prevalence of disease, the occurrence of epidemics, sanitary legislation, and related subjects. Volume 31 contains several articles on water.

Pollution of streams by municipal sewage. (Court decision), p. 1 and 29.

Sewage discharge into streams. (Court decision), p. 421.

AVater company required to supply pure water. (Court decision), p. 817.

The sewage pollution of streams and its relation to public health. W. H.

Frost. p. 2487.

The water supply of Youngstown, Ohio. Carroll Fox. p. 2667.

Drinking water on interstate carriers. J. 0. Cobb. p. 2845.

The water supply of Birmingham, Alabama. Carroll Fox. p. 3101.

UNITED STATES GEOLOGICAL SURVEY

George Otis Smith, Washington, D. C, Director. The Survey has charge of stream measurements and other investigations of water resources of the country. Water-Supply Papers are issued at frequent intervals.

SANITARY DISTRICT OF CHICAGO

Established in 1890. Thomas A. Smyth, president; George M. Wisner, chief engineer, Karpen Bldg., Chicago. The Sanitary District of Chicago has continued its investigations of 'sewage disposal for Chicago during 1916.

LAKE MICHIGAN SANITARY ASSOCIATION

Established in 1908. A. J. Horlick, Racine, Wisconsin, president. This association, whose object is the protection of water supplies, is composed of representatives of city councils, health departments, and engineering departments of cities in Lake Michigan drainage basin.

NORTH SHORE SANITARY ASSOCIATION

Established in 1908. James O. Heyworth, Lake Forest, president; James F. King, Lake Forest, secretary. This association advocates proper sewage disposal and water supply for municipalities on the "north shore" of Lake Michigan, and its work until recently has consisted mainly in accumulating necessary data and promoting a campaign of education. A bill passed in 1913 by the State Legislature granted permission to organize a sanitary district in Lake County, and on April 7, 1914, the North Shore Sanitary District, extending as far north as the north limits of Waukegan, was formally organized by a vote of the people. W. J. Allen of Waukegan was elected president of the North Shore Sanitary District.

LAKE MICHIGAN WATER COMMISSION

Established in 1908. Dr. G. B. Young, Health Commissioner, Chicago, president; Dr. Edward Bartow, director State Water Survey, University of Illinois, Urbana, secretary. The Lake Michigan Water Commission has for its object the investigation of the sanitary conditions of Lake Michigan, with a view to conserving a pure supply for cities and towns that depend on Lake Michigan for water. The commission comprises representatives from the United States Army and the United States Public Health Service and members, usually officials, are appointed by the governors of the States and the mayors of several cities which border the lake. No special appropriations are made for this commission. The eighth meeting was held March 19, 1915.

INTERNATIONAL JOINT COMMISSION

For the United States, Obadiah Gardner, Chaix*man; Whitehead Kluttz, Southern Bldg., Washington, D. C, Secretary. For Canada, Charles A. Magrath, Chairman; Lawrence J. Burpee, Secretary. Problems involving the sanitary condition of the boundary waters between Canada and the United States are referred to this commission. The following report was published in 1916.

Pollution of boundary waters. Report of the consulting sanitary engineer upon remedial measures. Earle B. Phelps. (159 pages).

CHICAGO HEAL ESTATE BOARD

A special report, prepared by George A. Soper of New York, John D. Watson of Birmingham, England, and Arthur J. Martin of London, England, gives their findings concerning water supply and sewage disposal for Chicago.

The water supply is not entirely free from pollution. The policy of using the rivers, and construction canals, as open sewers, is not in accordance with good sanitary practice. Intercepting sewers, screens, and settling basins will have to be employed extensively and it is probable that more efficient methods of purification will be required to a considerable extent. Trade wastes should be dealt with at private expense when they add unduly to the cost of treating the sewage. Sewage purification must be accompanied by filtration of the water supply. A definite general plan showing what will be needed during the next fifty years should be prepared.

AMERICAN PUBLIC HEALTH ASSOCIATION

Established in 1872. Dr. John F. Anderson, New Brunswick, N. J., president; Prof. Selskar M. Gunn, 755 Boylston St., Boston, Mass., secretary. The 1916 annual meeting was held at Cincinnati, Ohio. The official publication of this association is the American Journal of Public Health, a monthly magazine. "Standax*d Methods of Water Analysis" is also published by this association. Volume 6 of the official journal includes sevex*al articles of interest to waterworks men.

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Weston, Robert Spurr, Tests of a process of sewage purification with grease recovery and apparent profit.

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AMERICAN WATER WORKS ASSOCIATION

Established in 1880. Leonard Metcalf, Boston, president; John M. Diven, Troy, N. Y., secretary. The 1916 annual meeting was held in New York City. In 1914 the association began the publication of a quarterly journal which takes the place of the annual proceedings heretofore issued. Volume 3 of the Journal (quarterly) was published in 1916. It contains many interesting articles.

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Brush, William Whitlock, Freezing of water in subaqueous mains laid in salt water and in mains and services laid on land.

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Winslow, C.-E. A., Tests for Bacillus Coli as an indicator of water pollution.

Wolff, Mark, Interpretation of waterworks accounts.

Van Buskirk, L. H., Some problems of the State water laboratory.

ILLINOIS SECTION, AMERICAN WATER WORKS ASSOCIATION

Established as Illinois Water Supply Association in 1909 and became a section of the American Water Works Association in 1915. Paul Hansen, Springfield, president; Dr. Edward Bartow, Director State Water Survey, University of Illinois, Urbana, secretary-treasurer. It is composed of persons interested in the waterworks and water supplies of Illinois. Papers dealing with topics of interest to waterworks men are read at the annual meetings which are held at the University of Illinois in February or March. A second meeting is held elsewhere in the fall.

WESTERN SOCIETY OF ENGINEERS

Established in 1895. B. E. Grant, 207 City Hall, Chicago, president; E. N. Layfield, 1735 Monadnock Bldg., Chicago, secretary. The annual meeting is held in Chicago.

The official publication is a monthly journal. Volume 21, issued in 1916, contains the following papers:

The Wilson Avenue water tunnel, Chicago. Henry W. Clausen, Assoc. W. S. E. p. 373.

Investigation of flood flow on Wisconsin River at Merrill, Wisconsin. Clinton B. Stewart, M. W. S. E. p. 717.

ILLINOIS SOCIETY OF ENGINEERS

Established in 1885. Paul Hansen, Springfield, president; E. E. R. Tratman, Wheaton, secretary-treasurer. Water-supply and sewage-disposal problems form an important part of the work of the members of this organization. The official publication in 1916, the Thirty-first Annual Report, contains several papers and reports relating to water and sewage.

Bartow, Edward, and Mohlman, F. W. Activated sludge method of sewage disposal. p. 45.

Brooks, B. Erosion of watersheds and its prevention. p. 64.

Campbell, N. N. Sewage-disposal plant at Lake Forrest, Ill. p. 40.

Chamberlain, E. J. See page investigations. p. 59.

Habermeyer, G. C. Earth dam construction. p. 71.

Hatton, T. Chalkley. Experiments with activated sludge at Milwaukee, Wis. p. 49.

Report of committee on drainage. p. 58.

Report of committee on sewerage and sewage disposal. p. 54.

Report of committee on waterworks. p. 67.

Stanfield, A. C. Sewage treatment plant at Pana, Ill. p. 33.

Williams, C. B. Water softening at Hinsdale, Ill. p. 73.

ILLINOIS ACADEMY OF SCIENCE

Established in 1907. William Trelease, Urbana, president; J. L. Pricer, Normal, secretary. The functions of the academy are the promotion of scientific research, the diffusion of scientific knowledge, and the unification of the scientific interests in the State. All residents of the State who are interested in scientific work are eligible to membership. Transactions have been published annually since 1907.

Transactions for 1915 contain five articles on water supplies.

Bartow, Edward, Examination of drinking water on railway trains, p. 71.

Bennett, A. N., The arsenic content of filter alum used by Illinois water-purification plants. p. 75.

Corson, H. P., Manganese in Illinois water supplies. p. 82.

Hinds, M. E., The longevity of Bacillus coli and Bacillus typhosus in water. p. 78.

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